THE

JOURNAL OF GEOLOGY

JULY-AUGUST, 1898

THE ULTERIOR BASIS OF TIME DIVISIONS AND THE CLASSIFICATION OF GEOLOGIC HISTORY.

It was intimated in the introduction to the symposium on the classification and nomenclature of geologic time divisions published in the last number of this magazine that the ulterior basis of classification and nomenclature must be dependent on the existence or absence of natural divisions resulting from simultaneous phases of action of world-wide extent. If there have been such universal phases and if they can be detected, they must ultimately be accepted not only as the true basis of division, classification and nomenclature, but their exposition must constitute the major work of research and of instruction. The most vital problem before the general geologist today is the question whether the earth's history is naturally divided into periodic phases of world-wide prevalence, or whether it is but an aggregation of local events dependent upon local conditions uncontrolled by overmastering agencies of universal dominance.

That there were no universal breaks in sedimentation or in the fundamental continuity of life is not only admitted but affirmed without hesitation. The old doctrine of physical cataclysms attended by universal destruction of life has passed beyond serious consideration. And so, in the judgment of the writer, have all doctrines which attribute profound effects on the life of the globe or the progress of sedimentation to the violence of physical disturbances of any kind. That sedimentation has

been in constant progress somewhere since the inauguration of the pre-Cambrian lands and seas, and that life has been likewise continuous and self-derivative, may be accepted as fundamental postulates. If, therefore, we seek for *absolute* divisions we doubtless seek in vain. But this does not dismiss the question whether this continuity of physical and vital action proceeded by heterogeneous impulses or by correlated pulsations. If the latter, then the history of the earth, when deciphered, will assume a rhythmical periodicity susceptible of natural classification and of significant and rational nomenclature; if the former, the contradictory phases of local actions will inhibit all but the most general unity and render classification and nomenclature either arbitrary or provincial.

I venture to urge three general grounds upon which I entertain the former view. These grounds, if valid, hold out the hope that the history of the earth will be found not only susceptible to natural division, but capable of its truest exposition only through the recognition of its inherent periods.

I. The first of these grounds is the presumption that great earth movements affect all quarters of the globe. Minor stresses may find relief in local readjustment, but profound stresses cannot be relieved, it is assumed, without generating appreciable stresses in other portions of the globe and leading to general readjustment. In a globe, all of whose parts owe their positions to the stress and tension of other parts, every rearrangement that rises in magnitude above the limits of local support extends its influence to the whole. Any massive earth movement must change the gravitative stresses of all parts of the globe unless the movement be divided into contrary phases so adjusted as to be compensatory, the possibility of which in the strict sense may be questioned. The recognized causes of profound movements such as secular refrigeration, change of speed of rotation, progressive molecular rearrangement, and like agencies, are comprehensive in their action and accumulate general stresses whose natural issue is coöperation in a common movement of relief.

The validity of this presumption of general coöperative movements will perhaps not be so much questioned as the mode of their execution. There are those who believe that a downward movement in one region is correlated with an upward movement in some other region. The correlated movements have, therefore, opposite phases and if the distribution of these is not controlled by some unifying agency the general terrestrial effects are heterogeneous, or, if not that, at least uncertain. This view is the natural sequence of the doctrine of a thin, floating crust warping to satisfy its own changes of density and tension, and wrinkling to adapt itself to a shrinking nucleus. Accepting the truth that lies under this view, but rising to a broader generalization, there are those who entertain the conception that the depressions of the earth's surface habitually became more depressed with every readjustment to smaller dimensions (local exceptions aside), while the protuberances became more protuberant. In other words, the oceanic basins became progressively deeper and more capacious, while the continents became higher (degradation aside). In this assumption of habitual downward movements of the ocean bottoms and of correlative upward movements of the continents, there lies, if it be true, a basis for the natural division of geologic events, these movements being in themselves and in their immediate consequences the basis of such division. The full establishment or overthrow of this assumption must await the extension of critical research to at least the major part of the earth, and it is not the purpose of this paper to seriously attempt its advocacy by the citation of the evidence already gathered in its support. Incidentally it will be touched upon in the discussion following.

II. The second ground of belief in a fundamental periodicity in terrestrial progress is founded on the conviction that the major movements of the earth's surface have consisted of the sinking of the ocean bottoms and the withdrawal of additional waters into the basins whose capacities were thereby increased. This belief is not quite identical with the assumption last made, for it does not necessarily involve the simultaneous action of

the different ocean beds, although the conclusions about to be urged would be strengthened if such common action could be demonstrated. But quite apart from this, it is believed the following argument rests upon rather firm observational and inductive grounds except in the matter of two fundamental postulates which are almost universally assumed by geologists. These are as follows: (1) It is assumed that the earth was at first a nearly perfect spheroid, the surface being essentially plane. (2) It is assumed that the great movements of the earth's crust have consisted fundamentally of shrinkage. Probably no serious geologist maintains that the earth has enlarged its average diameter during geological history by expansive action, whatever he may hold respecting local expansion.

These two propositions being accepted, it follows that the radial shrinkage of the ocean bottoms has surpassed the radial shrinkage of the continental platforms to the average amount of some 10,000 or 12,000 feet. This excess of radial shrinkage is to be multiplied by four to measure the excess of volumetric shrinkage, since the area of the ocean bottoms is about four times the area of the continental platforms. The master factor, therefore, in the surface movements of the earth has been the sinking of the ocean bottoms and the formation of the great oceanic basins. Most geologists will probably agree that the continental platforms have also sunk, in the sense that they have shortened their radial distances from the center of the earth. Opinion seems to be divided, however, on the question whether there have been actual epeirogenic uplifts or not. Probably most geologists would regard the rising of the Thibetan plateau in late Tertiary times as involving an actual increase of radial distance. Probably very few geologists would question the absolute elevation of the crests of the loftier mountain ranges. However, the question of absolute as distinguished from relative sinking does not seriously affect the question in hand. If the earth has absolutely grown smaller by some notable amount the average ideal ocean has, as a consequence, grown deeper (if its volume has remained constant), for its circumferential expanse

has been reduced. Aside from this, so far as I can see, our argument holds as firmly for relative as for absolute sinking.

From the greater depths to which the ocean bottoms have sunk, the presumption follows that in every great crustal readjustment the major factor consisted of the descent of the ocean bottom or some part of it. Logically, as here stated, this is only a presumption which might be set aside by the assumption of a single or a few great depressions, while the other movements might be upward or indifferent, but this will appear less tenable in the light of further considerations.

Not only has there been increase in depth, but increase in capacity also. From a capacity essentially zero at the outset the basins have developed a capacity sufficient to hold nearly all the water of the globe. In the aggregate, therefore, the capacities of the ocean basins, as well as their depths, have been increased by crustal readjustment, and the presumption is that this has usually been the case in individual readjustments, although this does not rigorously follow. It will be sustained, however, by further considerations. The crustal readjustments here referred to are those resulting from internal causes. External readjustments work to precisely opposite ends, the degradation of the land and the filling of the basins. This opposing action strengthens the presumption that the internal causes have habitually increased the capacity of the basins, for they have grown more and more capacious in spite of this constantly opposing action. This constant filling in affords a presumption of frequently repeated increases of capacity; otherwise the land should have disappeared.

Proceeding upon the presumption that internal readjustments habitually increased the capacity of the ocean basins, it is important to note in detail the consequences that follow. These are involved in the functions of the circumcontinental terrace, and will be more easily followed after an explicit statement of these functions. These are more or less fully apprehended by all acute students of continental evolution, but like the correlative functions of baseleveling previous to the explicit exposition

of Powell, they have not come into that large service as working principles of which they are susceptible.

Every continent which stands in a given position with reference to the sea for any prolonged period develops a submarine terrace about its borders. This is formed from the débris of the land deposited beneath the edge of the sea. In its initial stages it is nothing more than the familiar shore terrace; but as it develops it becomes a broad submerged platform with a steep face dropping away to the abysmal depths of the ocean. The submerged platform has its outer limit at the depth at which detritus can be effectively moved off shore by the agitation of the surface waters. This, though varying with conditions, may be roughly taken to be one hundred fathoms. The breadth attained by the upper surface of the terrace is conditioned upon the length of time the continent remains in a fixed attitude and the activity of land wash. Simultaneously the sea cliffs are moving inland, and the valleys are developing base plains which are the correlatives of the terrace plain which is growing seaward, as illustrated in Fig. 1.

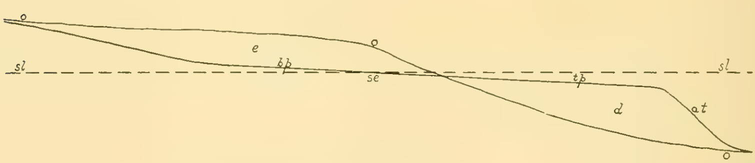

FIG. 1.—*o-o* Original surface. *s l* Sea level. *e* Land carried away by erosion. *d* Detritus built into circumcontinental terrace. *t p* Terrace plain. *a t* Abysmal terrace face. *b p* Base-plain developing landward.

The extreme limit of development is attained when the continent has been baseleveled and no farther detritus is furnished for the extension of the terrace. The baselevel of the continent then becomes essentially continuous with the submerged terrace surface, and the whole constitutes the perfected continental platform, as shown in Fig. 2.

The development of the circumcontinental terrace and of the perfected continental platform is subject to intercurrent disturb-

ances from local and from general sources. There appear to be two systematic sources of slight but very critical modification that require special consideration.

FIG. 2.—*b p* Continental base-plain. *s l* Sea level. *t p* Submerged terrace plain. *a t* Abysmal terrace face.

1. The transfer of débris from the land to the sea displaces an equivalent amount of water, and raises the sea level proportionately, and causes an advance upon the land. The effects are volumetrically small compared with the great body of the ocean, but a slight rise in the surface as the baselevel stages of the continent are attained is peculiarly effective. This coöperates with the cutting back of the sea cliff, and, combined, they become effective in advancing the edge of the sea upon the border of the land.

2. There are both theoretical and observational grounds for the belief that in the process of periodic readjustment of the earth to its internal stresses, portions of the crust are thrust up to heights notably above the plane of isostatic equilibrium, and that these portions gradually settle back toward equilibrium by virtue of the slow fluency or quasi-fluency of the rocks. Recent pendulum studies by Putnam and Gilbert seem to indicate that the portion of our continent most notably lifted in late Tertiary times still stands appreciably above isostatic equilibrium, and there is little doubt that the same is true of other continents, as is, indeed, indicated by partial pendulum data. There is, however, a large mass of concurrent data which shows an aggregate subsidence of the continent since late Tertiary times, data which have been industriously marshaled in the interests of an epeirogenic explanation of the glacial period. This leads to the impression that in late Tertiary times, when the upward move-

ment reached its maximum effects, the land stood very notably above isostatic equilibrium, and that it has been settling back, but has not even now reached isostatic equilibrium. While the generalization cannot be rigorously established, there seem to be sufficient data to warrant entertaining tentatively the doctrine that in periods following crustal upheavals which pass beyond the plane of equilibrium the lifted portions slowly settle back toward equilibrium. If so, this retrocession would coöperate with the filling of the basins in causing an advance of the sea upon the land. At the same time the conditions for the seaward growth of the terrace plain may still continue and the plain be thus simultaneously extended on both borders.

As already noted, the evolution of this peri-coastal plain is subject to interruptions and local modifications to an extent comparable to the interferences in the development of a base-plain, and perhaps to a greater degree, but I think it has like claims to acceptance as an effective general process.

Now the development of such submerged terraces around the several continents for any given period is accurately correlated by the sea level. They are all built immediately beneath its border at a common level. The continental baselevels are correlated by the same controlling horizon. So, necessarily, the final continental platforms are likewise reduced to the same common natural datum plane.

If, therefore, it be admitted that there are periods of general quiescence, it follows that there are periods of simultaneous platform-making just below and just above the sea level on all continents. And this is accompanied by an inevitable tendency of the sea to advance upon the land. Now this submerged sea shelf is the special zone of sedimentation, and hence it is the peculiar locus of registration of geologic events. It is at the same time the peculiar habitat of shallow-water marine life, and this is the life which specially enters into the geologic record. We know almost nothing of the ancient abysmal life and relatively little of the land life. Both the physical and the biological record, which are our chief dependence in reading the

earth's history, are therefore made upon the surface of the peripheral terrace and of its inland extension, and hence this becomes preëminently a critical geologic zone.

To follow out the sequence of a typical cycle, let it be supposed that a circumcontinental submarine platform of ample dimensions has been developed, and that it is peopled by a fauna comparable to its extent and resources. It has been suggested that a typical crust movement has for its major feature the depression of the sea bottom and an increase in the capacity of the basin. Let such a movement succeed. The effect of this, whether it involves one ocean basin or all, must be the withdrawal into itself of water from the submerged platforms of all the continents alike, since the oceans are connected. If the basin movement has sufficient magnitude to draw down the sea surface to the terrace edge, the shallow water zone becomes narrowed to a mere strip on the rapidly shelving abysmal face of the terrace, as illustrated in Fig. 3.

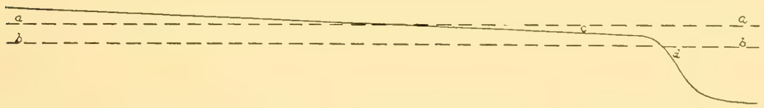

FIG. 3.—*a* Former sea level. *b* Succeeding sea level. *c* Former ample shallow-water tract. *d* Succeeding constricted shallow-water tract.

The ample fauna of the previous broader tract is thus forced into the constricted zone and brought under the direst stress of competition and scant room. The destruction of the larger part is inevitable, and the residue is forced to undergo repressive evolution to meet the severe conditions of the new environment. As this is common to all continents, it constitutes a comprehensive evolution of the severely competitive phase. There would, to be sure, be such exceptions as the local variations from the typical configuration of the continental border afford. These might be very considerable. Portions of the continents may have been previously carried down to moderate depths in the sinking of the ocean basins and may become shallow water ground by

the lowering of the sea level. But even then there would remain a community of dominant action that would give a decisive aspect to the progress of life and to the sedimentation on all continents alike.

If now a long period of quiescence follows, a new universal terrace will begin to form and will extend its marine plain seaward and its baselevel inland until at length an ample zone for the evolution of a new shallow water fauna is provided. If to the cutting of the sea edge and the filling in of the sea basin there be added the settling of the continent, the sea may make a wide incursion upon the low parts of the land, as it did in Cretaceous times, and unusual facilities be thus afforded for that form of life-evolution which follows rich and genial conditions.

Thus on the one hand the sinking sea bottom induces that form of evolution in which stress is the dominant factor, and on the other, quiescence induces that form of evolution in which new ground and rich opportunities constitute the dominant condition. Both of these follow simply and inevitably from the sinking of parts that have been already predominant in sinking, and from prolonged intervening stages of quiescence. Almost the only essential postulate of the one evolution is a periodic increase of sea basin capacity; of the other, periodic quiescence. No profound catastrophe is involved; rather on the contrary it is inhibited by the conditions postulated.

Both the evolution of restrictive environment and the evolution of expansive environment, in the opinion of the writer, are effective in the change of faunas, though their respective results may be as different as their modes. In the rhythmical action postulated there is an alternating application of these opposed evolutionary processes with the natural result of an effect of the maximum order; for the evolutionary effects of restrictive conditions are believed to reach their greatest magnitude when they follow conditions of expansion, and, reciprocally, expansive conditions realize their greatest results when they follow conditions of restriction.

Such a succession of shallow sea incursions and withdrawals

reciprocating with crustal movements and quiescence seem to me to be well indicated as the master features of geologic progress from the beginning of the Palæozoic era to the present time. To these features I look for the primary terms of a natural and permanent system of classification and nomenclature.

III. The third agency which affords some promise of becoming a means for strict correlation of transoceanic events and for the division of these events into their natural epochs is an assumed fluctuation in the constitution of the atmosphere. Too little has yet been learned by direct induction respecting the nature of the successive atmospheres of the geologic periods to render this a firm ground for conclusions, but I venture to invite attention to the doctrine enunciated some time ago[1] that the exposure of the crystalline areas to the action of the air necessarily led to changes in the constitution of the atmosphere, especially in the critical element of carbon dioxide. The principle was urged that the greater the exposure of the decomposable crystalline rocks in area and in elevation, by leading to wider contact and deeper penetration of the atmosphere and atmospheric waters, the more rapid must have been the decomposition of the crystalline rocks and the consequent consumption of carbonic acid in the carbonation of the alkalis and alkaline earths, which is the most important part of the decomposing process. This greater exposure obviously followed the crustal readjustments, for at these times the land was largest and highest. It then not only exposed the greatest surface to atmospheric contact, but the atmospheric waters penetrated deepest because of the hydrostatic pressure arising from great differences of water level. At times of approximate degradation to baselevel and of sea-border encroachment the area of action was reduced and the power of penetration of the atmospheric waters became slight because of the low elevation and consequent slight differential pressure. In a word, the consumption of the carbonic acid proceeded rapidly at times of broad and

[1] A Group of Hypotheses Bearing on Climatic Changes. JOUR. GEOL., Vol. V, No. 7, October-November 1897.

high elevation of the land, and slowly at times of low altitude, grand averages being always understood.

If the atmosphere were once excessively burdened with carbonic acid and its later history has been merely a progressive depletion, these stages of rapid consumption only introduced specially rapid reduction of the superabundant supply, and the effects on tangible geological processes may have been quite beyond detection. But if, on the other hand, the atmosphere was limited in amount at the beginning and has been gradually supplied as well as gradually consumed throughout the ages and has been susceptible to serious change, an unusually rapid consumption of the carbon dioxide at the stages of land elevation would result in appreciable depletion of the atmosphere unless the supply were correspondingly increased. On the other hand, at those stages in which the continents were reduced well toward sea level and the land areas were diminished by the incursion of the ocean, the consumption of the carbonic acid would be checked, and if the supply were not correspondingly reduced, reënrichment in carbonic acid would follow. Under this hypothesis, the history of the atmosphere involved alternate enrichment and depletion.

The carbon dioxide is critical because of that peculiar thermal capacity by virtue of which it retains the heat of the sun to a relatively extraordinary degree, a capacity which is shared by water vapor, but which is possessed in very low degree by oxygen and nitrogen. The amount of aqueous vapor, however, is dependent upon temperature, while the carbon dioxide is stable and active at all terrestrial temperatures. Whenever, therefore, there is a notable percentage of carbon dioxide in the atmosphere, it performs a most important function in conserving the heat of the sun and raising the temperature of the lower atmosphere and of the earth's surface. By this rise it increases the aqueous vapor in the atmosphere, which in turn aids the carbon dioxide in retaining the heat of the sun, the two acting conjointly. On the other hand, when the carbon dioxide is reduced to a small factor, the heat of the sun is less effectually

retained at the surface of the earth, the water vapor enters less into the atmosphere and low temperature and aridity are the consequences.

If these considerations are valid, the history of the earth has been marked by periods of relative cold and aridity resulting from stages of rapid rock disintegration, alternating with periods of warmth and moisture correlated with periods of limited rock disintegration and of carbonic acid accumulation. These stages are genetically connected with periods of continental elevation and rapid subaërial degradation, on the one hand, and with slight degradation and sea incursion, on the other. It will be observed that continental elevation as a purely topographical condition contributes to cold and aridity, while continental degradation correlated with oceanic extension contributes to equalization of temperature and to warmth. We have, therefore, the conjoint action of topographic agencies with atmospheric constitution in producing alternations of cold and aridity with warmth and moisture. The aridity is thought to express itself in salt and gypsum deposits and in the red sediments with which these are habitually associated; the cold, in glaciation; the warmth and moisture, in the polar extension of tropical life.

Now these atmospheric influences are strictly simultaneous for all parts of the globe, latitudinal effects, of course, being neglected, for the diffusion of the atmosphere is such as to render its constitution practically uniform for all parts of the globe. In so far, therefore, as atmospheric conditions of a constitutional nature affect the progress of terrestrial phenomena, they affect them universally, and if these influences are pronounced and can be identified they furnish an additional basis for the strict correlation of transoceanic action and for the division of geological history into its natural epochs.

In summation, therefore, I rest in a somewhat confident hope that under continued study adequate natural bases for the more important divisions of geologic time and for a stable and fitting nomenclature will be found (1) in simultaneous internal readjustments alternating with intervals of relative quiescence, (2)

in the periodic development and emergence of circumcontinental terraces and their critical effects on the evolution of life, and (3) in the successive depletions and enrichments of the atmosphere. For subdivisions of lower order the migration of faunas and the special features of continental development will furnish appropriate bases, and below these again, the local phases of sedimentation and faunal adaptation will afford the provincial terms of a natural classification. If this hope be well grounded, the arbitrary divisions that now vex our system may be largely eliminated.

T. C. CHAMBERLIN.

THE POSTGLACIAL CONNECTICUT AT TURNERS FALLS, MASS.

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THE familiar slabs of sandstone with fossil footprints from Turners Falls come chiefly from the "Bird Track Quarry," about a mile from that village on the opposite side of the Connecticut River.[1]

The quarry is on the west shore of a little sheet of water known as the Lily Pond, which is steeply walled with rocks on three sides, opening on the north to a tract of marsh and a stagnant arm of the river called the Cove. These details are clearly shown in Fig. 2, giving on a large scale the actual topography of the region about *A* and *B* in Fig. 1. Fig. 2 is *not* taken from the state map.

The Lily Pond is the pool of an abandoned waterfall made by the Connecticut some time since the last glacial epoch, and occupied long enough for it to cut back an eighth of a mile in the Triassic sandstone. When this path was abandoned the river was fifty feet above its present bed. Fig. 3 shows one wall of the little gorge at the point where the quarry is situated, looking across the pond from the opposite side. The quarry is just beneath the pine tree in the center, the rejected slabs forming the talus heap below.

[1] *A*, Fig. 1.

The rocks about the pool are waterworn in precisely the same way as the similar sandstones beneath the present falls at the village. The edges of the shaly laminæ are frayed and rounded

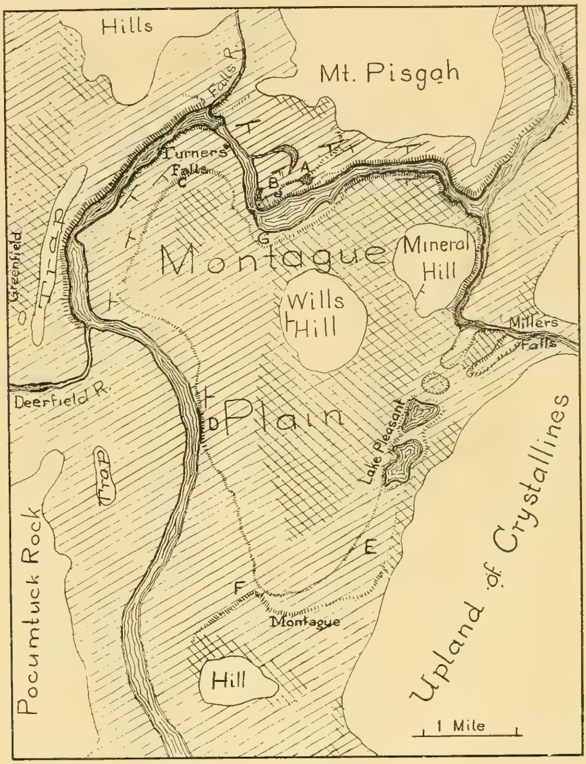


FIG. 1.

as appears in Fig. 4, which is a view of *P* looking from *O* in Fig. 2. Similar effects are observed on all the rocks about.

Besides this fraying of edges, a clear indication of water action, is the complete absence of glaciation about the pool, though elsewhere these sandstones and shales show unmistakable smoothing and grooving on every ledge. Here, despite the rounding in detail, the mass contours of the rocks are sharp and jagged. They have been deglaciated in the rush of waters.

Half a mile further southwest along the same ridge of red shales is Poag's Hole, a similar gorge, somewhat deeper, but of comparable area. Fig. 5 shows the western rock wall. The

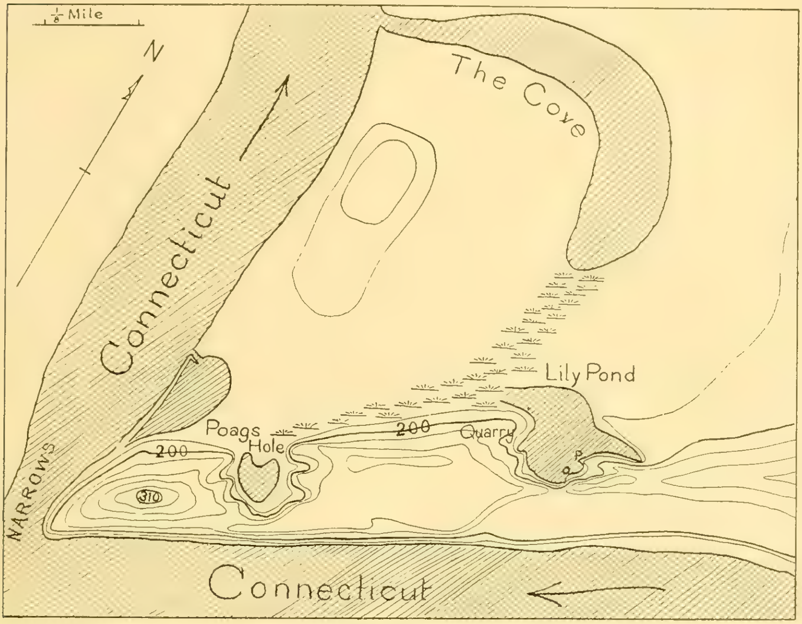


FIG. 2.

crest of the wall at the back is about twenty feet above the crest at the Lily Pond and the sills in front of the pools have nearly the same difference of level. This fall, then, was cut by the river earlier than that at the Lily Pond.

The ridge in which these two gorges are cut has a northern front of exposed shales and sandstones, which strike a little north of east and dip moderately to south. The strata are continuous across the gorges and were once everywhere overlain by clays under sands and gravels, all of glacial origin. The clays are now exposed in the 270-foot flat on the south side of the ridge, between Poag's Hole and Lily Pond. The highest point on the

promontory, west of Poag's Hole, is a cap of gravelly sands that bring it up to the level of Montague Plain, of which it was doubtless once a part, most of the sand and clay having been

FIG. 3.

removed by the river as it cut its way down toward the rock. Fig. 6 is a section through the highest point of the ridge just west of Poag's Hole,

Montague Plain is roughly outlined in Fig. 1, the single-lined area suggesting the original extent of the plain formation, and the cross lined part being still at about the original level. The upper portion of the plain is everywhere of sand and gravel somewhat irregularly stratified.

The formation has a considerable extension in Greenfield Meadows and lesser ones to north and south. The gentle undulations of the surface, together with the lack of sharp stratification suggests that the sands were not laid down in standing water, but rather strewn here and there by the detritus-laden

floods from the melting ice on the hills, checked here in their steep descent, and arriving largely through the valleys of the Millers and Falls rivers.

FIG. 4.

Under the sands are clays observed at various levels from 190 to 270 feet above the sea. They rest on the glaciated sandstone, are beautifully stratified, occurring mostly in half-inch layers, greenish and butter-like, with gritty sandy layers from two to four inches thick between. They are exploited for brickmaking at several points in the escarpment around Montague Plain.

In the clay pits beside the track at Greenfield the stratification is clear and horizontal as elsewhere. but the upper surface of the clays, as revealed by the workmen, is uneven and not parallel to the stratification, while the transition from clay to

gravel is abrupt. At Keith's Spring (Fig. 1, *G*), 200 feet above sea, is a little hill of the laminated clays at the foot of the bluff, with its strata running squarely into the sand of the bluff across the intervening air. No other agency than the different rates of atmospheric wear on clay and sand is apparent to account for the notch between the clay hillock and the bluff. A similar hillock of laminated clays occurs half a mile further north. These three occurrences and the varying upper limit of the clays observed point to erosion of the clays before the sands were laid down. Yet in several of the sections the true surface may be masked by sand that has fallen down from above.

The present course of the Connecticut around the plain is of course postglacial and much of it is gorge cut in the rocks. Such rock-cutting is indicated on the map by heavy lines on the river margin. Though superposed on the rock structure underlying the plain this part of the river has now a certain adjustment to the structure as may be seen by the stratigraphic marks on Fig. 1 which indicate well-established facts.

Preglacially the channel was probably straight down from the northeast corner of the map by Millers Falls, and Lake Pleasant and thence westward to the present channel somewhere between *D* and *F*, points where ledges are now exposed.

Between the occupation of the ancient and modern channels there are indications of some persistence of the drainage across the plain by a west channel and an east channel. Indications of water passing through the west channel are:

(1) the gentle depression between *G* and *D* (Fig. 1), and (2) the frayed and waterworn state of a rock ledge at the 220-foot level (*D*), a hundred feet above the present river.

The east channel is better marked, being indicated today by deep sags in the plain at Millers Falls; kettles to the south, two of them occupied by the Lake Pleasant ponds; and the long deep valley to the south by which the lake drainage escapes to the river. The higher ground between the kettles is yet below the surface of the plain. This is shown in Fig. 7, taken

on the higher land between Lake Pleasant and the next kettle to north. The gentle hollow in the foreground represents the ground between the kettles. The tree tops in the middle dis-

FIG. 5.

tance indicate the location of the kettle.[1] Fig. 7 was taken to show that even if the kettles were filled up, there would still remain a shallow valley in the plain. The deeper southern por-

[1] This kettle, like the 100-foot cliff at *D* and some other features, does not appear on the Greenfield topographic sheet. The Lily Pond ridge also is quite misrepresented.

tion of the valley (at *E*) is in the clay, and brickyards are located there.

If the broad valley southwest from Turners Falls between the Greenfield trap ridge and the northwest bluff of Montague Plain was cut out by the modern river, it is remarkable that the cutting should have ceased a few feet above the rocks. But as

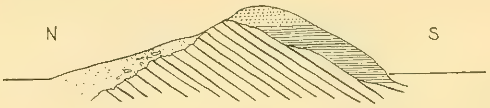


Fig. 6

these are beautifully glaciated and buried under a thin cover of drift, it is hard to believe the water has actually flowed over them. Moreover a curious remnant of sandplain (?) standing on the northwest corner of Montague Plain (at *C*) seems to indicate that ice filled this valley all through the building of the plain. The wearing back of the bluff has cut away most of this sandplain, but a section near Mr. Burnet's discloses the foreset beds and some of the topset. Sands on that side would have come from the hills to the northwest by the valley of the Falls River.

Kettles like those of the east valley we are wont to associate with drift-buried ice blocks. From the alignment with the old upper valley of the Connecticut, as seen in the northeast corner of the map, this chain of depressions might represent the burial in outwash sands of the decayed remnants of a valley ice tongue, the sands being supplied from the earlier revealed hills to north and east. The ice-tongue here however must have rested above the clays, unlike the tongue to the northwest. If this inference is correct, as the clay floor at *E* seems to make it, we must suppose the clays were laid down during a withdrawal of the ice-front from this area while it was either laked or depressed beneath the sea, and that subsequently the ice advanced again to southward, reaching its valley-tongue out over the clays where in the final melting of the ice it rolled

into a number of great fragments and was buried in the sands.

Chief attention is here called to the topographic facts which it is believed are accurately described. The succession of events

FIG. 7.

which seems most plausible is here offered as an hypothesis for present use. This hypothetical history is as follows:

1. Ice advance.
2. Ice retreat, leaving Turners Falls ice-tongue.
3. Deposition of clays.
4. Ice advance, east valley tongue overriding clays.
5. Ice retreat, leaving east valley ice tongue.
6. Building of Montague Plain and burying east valley ice.
7. Clearer waters pass through west valley.
8. Turners Falls valley ice melts, tempting Connecticut across the ridge where it cut successively Poag's Hole, Lily Pond and the Narrows.

9. East valley ice melts leaving modern topography.

10. The trenching river finds the rocks and cuts its gorge with present falls and rapids.

Ponds, such as those here described should be fairly numerous in glaciated regions. The kettle ponds are of course widely observed.

Pools of abandoned falls of glacial origin are not often cited. A superb example is noted by I. C. Russell[1] at the foot of a 400-foot basaltic cliff near Coulée City, Washington, over which the waters of the Columbia plunged when an ice dam drove them through the fault chasm of the Grand Coulée (p. 91). Another such pool is Thaxter Lake near Taylor's Falls, Minnesota, excavated by the tumbling waters of the deviated St. Croix.[2] Other fine examples are the Green Lakes at Jamesville and other points near Syracuse, reported by Gilbert and lately described by Quereau.[3] Here magnificent glacial outlets of Lake Iroquois, paralleling the Mohawk outlet, but farther south, cut broad trenches across the promontories of the ragged escarpment south of Syracuse and plunged Niagara-like into great basins below. The trenches are now dry high in the hills, but the basins are filled with placid greenish waters.

M. S. W. Jefferson.

[1] Bull. 108, U. S. Geol. Surv.

[2] Berkey, Am. Geol. Dec. 1897, p. 352.

[3] Bull. Geol. Soc. Am., Feb. 1898.

THE VARIATIONS OF GLACIERS. III.[1]

THE following is a summary of the Second Annual Report of the International Committee on Glaciers:[2]

RECORD OF GLACIERS FOR 1896.

Eastern Alps.— Nearly all the glaciers are receding, though a few have begun to advance. The Bavarian glaciers show a marked recession.

Swiss Alps.—The advance shown by many glaciers between 1880 and 1893 is fast disappearing. The Rosegg glacier (Engadine) is advancing, as were recently some glaciers on the not distant Ortler.

Italian Alps.—A considerable interest is being awakened in Italy in the variations of glaciers. The Italian Alpine Club, the Alpine Society of Frioul, and the Italian Geographic Society are all encouraging the study of glaciers. Those under observation in the central chain show a marked retreat. Eight glaciers have been examined in the Maritime Alps, and all seem to be diminishing.

Scandinavian Alps.— Much activity is being shown in Sweden in the study of the recently discovered glaciers, but it is still too soon for extensive results. One glacier, the Soltja, has advanced very slightly; the others seem to be stationary. Some interesting temperature observations were made. Minimum

[1] The first two articles of this series appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383.

[2] Archives des sciences phys. et nat., Vol. IV; Geneva, 1897. Some changes have occurred in the membership of the committee. Mr. D. W. Freshfield has replaced Captain Marshall Hall, deceased, as representative for Great Britain and her colonies; Professor G. Marinelli has replaced Professor T. Taramelli, resigned, as representative for Italy; Professor A. G. Nathorst has been appointed to represent Spitzbergen and other Arctic regions not belonging to any civilized nation. We have also to record the sad death of Professor Léon du Pasquier, at the beginning of a career full of promise.

thermometers, placed on the summits of certain mountains, recorded —17° C., against —40° in the neighboring valleys.

Greenland.— Mr. Steenstrup has attempted to determine whether the inland ice has suffered periodic variations, but has been unable to arrive at definite conclusions.

We have a description of the inland ice, written in the year 1200, which would apply to its present condition. A dozen glaciers in the Umanak fiord are the only ones that have been sufficiently studied to yield results of value. Some show no sensible variations; others show variations of rather short periods, dependent probably on the rate of flow. Generally it can be said that there has been no marked change in the length of the glaciers during this century, but the tendency seems to be for an advance rather than for a retreat. A table of twenty-six measures of the velocity of various Greenland glaciers shows motions ranging between one-quarter inch and 124 feet a day.

Professor Mouchketow, representative for Russia, makes the following report:[1]

Caucasus.— Measurements of nine glaciers in different parts of this chain show a retreat varying from 30 to 125 feet yearly for the last eight or ten years; though in the central Caucasus some of the névé fields are growing thicker. About forty glaciers were visited in 1896 in the mountains of Teberda and Maroukha, several of which were unknown before. They are receding, and we may say that the glaciers of the Caucasus are generally in the state of retreat.

Turkestan.— Many glaciers have been discovered in the Ghissar Mountains and the neighboring chains. They are small and do not descend below 11,000 feet. They occur in groups; the majority lie on the northern slopes, and are for the most part entirely covered with snow; this was more general than usual in 1896, on account of the heavy precipitation, which also characterized that year in the Alps. The positions of the moraines show a general retreat of these glaciers.

[1] Professor Mouchketow gives the names and locations of a large number of glaciers.

Siberia.—The principal observations are in the region of Beloukha; the glaciers show a very marked decrease in size.

RÉSUMÉ.

Although it is too early to attempt to form definite conclusions, still the reports seem to indicate pretty generally that the glaciers of the world are getting smaller. The few local cases of advances are of small importance. No region observed shows a general advance of its glaciers such as took place in the Alps in 1816–1820.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1897.[1]

But little information has been obtained regarding the variations of glaciers in the United States between 1896 and 1897.

Chaney Glacier, a small, steep glacier in the Rocky Mountains of Montana, discovered in 1895, is retreating. (L. W. Chaney.)

Carbon Glacier, on Mount Rainier, has retreated about seventy-five feet between 1896 and 1897. (Plummer.)

Mr. I. C. Russell reports a glacier on Mount Stuart, and Mr. M. W. Gorman reports glaciers on Bonanza and on North Star Mountain, all in the State of Washington.

The glaciers of the Kenai peninsula, Cook's Inlet, Alaska, have been mentioned, but not described, by earlier writers. Mr. F. H. Curtiss has sent me a short description, from which the following is condensed:

The ridge running along the southeastern side of Kachemak Bay is over 3000 feet high; the upper part is covered with snow, from which glaciers descend through deep gorges nearly to the sea level.

The tongues of the glaciers are about five miles long and from three-quarters to one and a quarter miles wide; they all have terminal moraines. A few have been named. The

[1] A synopsis of this report will appear in the Third Annual Report of the International Committee. The report on the glaciers of the United States for 1896 was given in this JOURNAL, Vol. V, pp. 381–383.

Grewingk has apparently retreated about 600 feet in fifteen years. The next glacier to the northeast, though fed by the same fields, seems to have receded very little.[1]

Mt. Iztaccihuatl, in Mexico, has a snow cap from which a small glacier, the Porfirio Diaz or Ameca, protrudes (a second glacier has retreated to the snow-line). Señor Ezequiel Ordoñez, of the Mexican Geological Survey, has put out signals to study its variations. Excellent descriptions and reproductions of photographs of this glacier have been given by Dr. Oliver C. Farrington, of Chicago, with references to the literature.[2]

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
June 28, 1898.

[1] A map showing a part of this region, with corrections by MR. CURTISS, has been published by Professor William H. Dall. Coal and Lignite of Alaska, U. S. Geol. Surv. 17th Ann. Rept., 1896, p. 786.

[2] Observations on Popocatepetl and Iztaccihuatl, Field Columbian Museum, Publication 18; Chicago, 1897. Dr. Farrington has overlooked the interesting pamphlet of SEÑOR EZEQUIEL ORDOÑEZ, Notas acerca de los ventiqueros del Iztaccihuatl; Memorias de la Sociedad Cientifica "Antonio Alzata;" Mexico, 1894.

NOTES ON THE KALAMAZOO AND OTHER OLD GLACIAL OUTLETS IN SOUTHERN MICHIGAN.

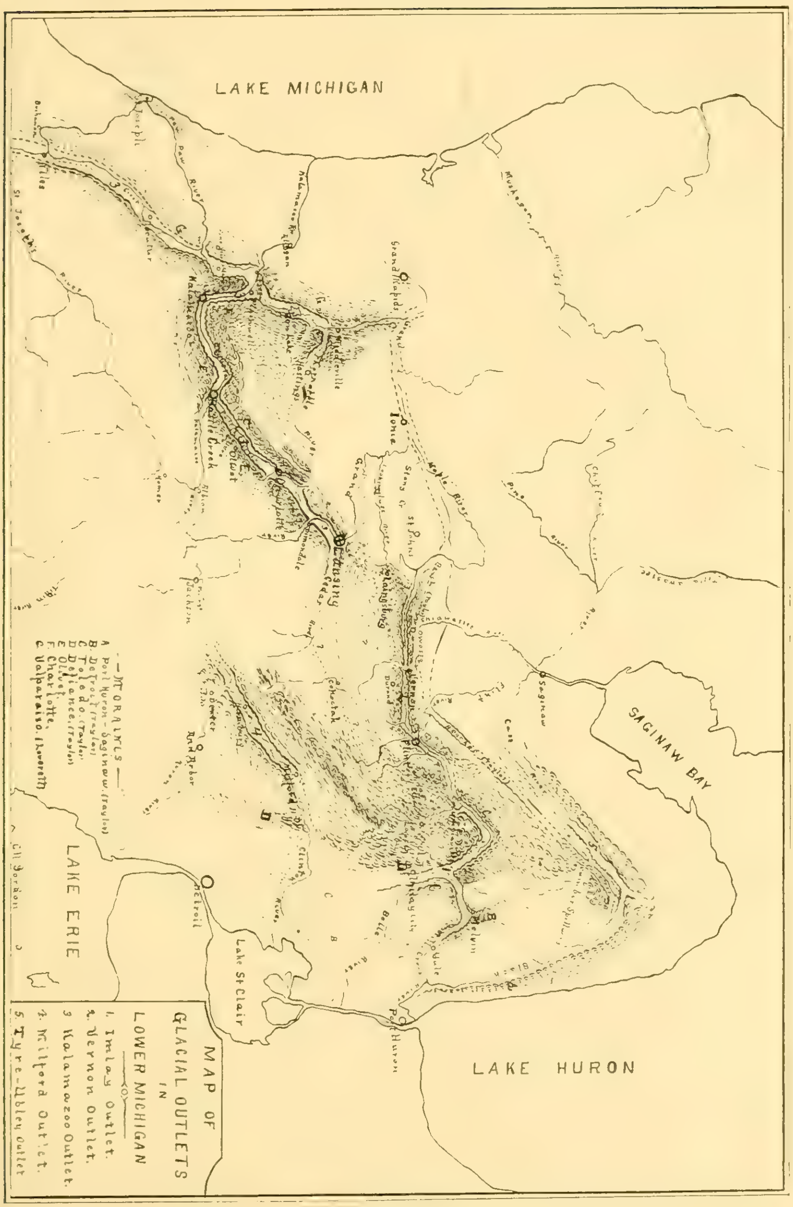
Having occasion recently to cross the state from Melvin near Port Huron to Plainwell, the writer took advantage of the opportunity to make the trip by wheel for the purpose of studying some of the problems of glacial drainage suggested by previous studies. It had been observed earlier that between Plainwell and Battle Creek the Kalamazoo River occupies a wide valley evidently of prior origin. Above Battle Creek the valley is much narrower, while a broader channel bears off to the northeast and furnishes an outlet for the Battle Creek. In eastern Michigan the observations of Taylor, Gilbert, and others have disclosed the existence of several old outlets, though the courses of some of them have not been completely traced. One of these, the Imlay, was traced by the above authors northward past Imlay to North Branch, thence southwestward to Columbiaville. Further, in a letter to the writer, Dr. A. C. Lane, Assistant State Geologist, has pointed out the existence of an old channel between Milford and Hamburg Junction, which is now occupied by the Huron River. Did the Imlay outlet discharge by way of the Kalamazoo or was the latter the outlet for the waters of the Milford channel? While the time at the writer's disposal did not permit a full investigation, the facts obtained are deemed of sufficient interest to warrant their publication as a contribution toward the elucidation of the glacial history of the state.

The Imlay outlet.—This outlet, described and mapped by Taylor,[1] was crossed by the writer near its summit level about ten miles southwest of Brown City. South of this point the swamp which marks the position of the channel is drained toward the northeast by Mill Creek. As far as Yale this creek

[1] Bull. Geol. Soc. of Amer., Vol. VIII, 1897, pp. 31–58.

flows in an old channel which probably received the glacial waters when the ice front had retreated to the position of the Detroit moraine at Melvin and poured them westward into the Imlay outlet. Near Columbiaville there are indications that the waters escaped southward toward Lapeer, following the line of the headwaters of the Flint River, while another smaller trough appears to lead southwest, crossing the line of the C. & G. T. Railway just west of Elba. The latter is well situated to constitute the continuation of the Imlay channel, but the elevation of the bottom of the valley, which is about 800 feet, or thirty feet above that of the Imlay at Columbiaville according to Taylor, would seem to militate against that conclusion. The relations here are somewhat obscure and more detailed investigations are needed to settle the question.

The Vernon outlet.— Below Columbiaville the Flint River crosses a moraine which is seemingly the Saginaw, equivalent of the Toledo moraine. At Flint also the river with an abrupt turn breaks through a northward lying parallel ridge which we take to be the equivalent of the Detroit moraine. The valley of the stream where it crosses the first mentioned moraine is much wider than where it crosses the second and has evidently been occupied for a longer time. Before passing through the break in the second moraine it receives a branch from the southwest called Swartz Creek. This stream flows in an old channel which was followed by the writer many miles westward along the south border of the moraine which we may here call the Vernon moraine, from the village of that name which is situated upon its slopes. West of Otterburn the Chicago and Grand Trunk Railway follows the valley bottom as far as Duffield, the stations here being nearly on a level with the valley floor. At Duffield the channel bears directly westward past Vernon. It was followed to a point about nine miles west of this place, or twenty-seven miles in all. The channel has a width of three-fourths of a mile and is covered in part by a black, mucky soil. In places where the drainage is not well established it is wet and swampy. At one point dredging revealed the presence of


LAKE MICHIGAN
SAGINAW BAY
LAKE HURON
LAKE ERIE
Lake St Clair
MAP OF
GLACIAL OUTLETS
IN
LOWER MICHIGAN
1. Imlay Outlet.
2. Vernon Outlet.
3 Kalamazoo Outlet.
4. Milford Outlet.
5. Tyre-Ubly Outlet
— MORAINES —

gravel beneath the muck. Outside the muck area which comprises a belt of varying width extending along the middle of the valley the floor is covered with sandy gravel. Bowlders are not abundant though one field was seen to be thickly strewn with them. Toward the east this portion of the channel is drained by Swartz Creek, which enters it from the south about a mile west of Swartz Creek station, and toward the west it is drained by a branch of Maple River. The middle portion is intersected by the Shiawassee River and one of its branches. The Shiawassee enters the valley about three miles west of Vernon and follows it to the latter place, where it breaks through the moraine northward. The further course of the channel westward is not known, but it probably either continues past St. Johns down Stony Creek or follows the Maple by way of Duplain to the old Grand River outlet. If the Vernon moraine is the equivalent of the Detroit moraine as we infer, then the Vernon outlet must have been active at the time the Mill Creek channel was open at Melvin, the waters from which found their way westward through the bend of the Imlay outlet, though at a later stage the latter may have been abandoned for an outlet farther north, possibly by way of Otter Lake. Within the limits described the known elevations of the channel floor as shown by the railroad levels at the stations named, which are generally within a few feet of the bottom level, are as follows: Otterburn 771, Swartz Creek 779, Crapo 774, Duffield 780, Vernon 780.

The Kalamazoo outlet.—This is one of the most important of the glacial outlets observed within the state. Previous observations had shown the existence of a channel between Battle Creek and Plainwell, but its extension east and west from these points was unknown. Our recent observations have shown that this channel extends northeastward from Battle Creek as far as Lansing, at which point it turns eastward, but beyond which it has not been traced. From this place to Plainwell it follows the outer border of a moraine (*F*), here named the Charlotte moraine from the city of that name which is situated upon it

Between Plainwell and Otsego it turns abruptly southward along the outer border of the Valparaiso moraine (*G*), past Decatur and Niles to South Bend, and thence evidently, according to Leverett's observations, the waters reached the Illinois River by way of the Kankakee. On the south and east side the waters were confined by the Olivet moraine (*E*). Between Lansing and Plainwell the channel has an average width of about a mile, but is somewhat wider in its lower portion. At the bend near Kalamazoo it has a width of two and a half miles and at Plainwell it is much wider. At Plainwell a branch comes in from the northeast by way of Gun Lake that is in direct connection with the upper part of the valley of the Thornapple River which is here wide and was evidently active as an outlet at a later stage than the Kalamazoo. The connection between the Thornapple and Gun Lake divisions is through a series of small lakes and marshes in Yankee Springs township.

Between Dimondale and Charlotte the Kalamazoo channel is marked by a long narrow marsh some portions of which have been brought under cultivation. Similar marshy tracts occur also between Charlotte and Battle Creek, at Kalamazoo and south of Otsego. At Kalamazoo the mucky soil has been utilized for growing the celery for which that city has become noted. Outside the mucky areas the channel floor is covered with sand and gravel. In some places sand predominates and often occurs in low mounds and ridges. Gravel, however, mixed with more or less sand is the principal constituent of the valley filling. Gravel beds occur along the sides of the valley as remnants of a terrace, the top of which is about fifteen feet above the general plain level. Cultivated fields generally show an abundance of cobble stones strewn over the surface and in some places bowlder patches occur. At Charlotte gravels constitute the low divide between the headwaters of Battle Creek and Thornapple River occupied by the Grand Rapids branch of the Michigan Central Railway. At Plainwell a bluff of gravel twenty feet high extends along the north bank of the river which here flows over a stony bottom.

At Dimondale the Grand River enters the valley from the southeast and follows it to Lansing, a distance of nine miles, where, after receiving Cedar River, it passes through the Charlotte moraine northwestward. The marshy tract between Dimondale and Charlotte is drained westward through the Thornapple, while below Charlotte the drainage is effected by Battle Creek. At Otsego the Kalamazoo leaves the old channel and passes out westward through a narrow gorge in the Valparaiso moraine.

The elevations of railroad stations which appear to be situated about on the level of the valley floor are as follows: Lansing (C. & G. T. R. R.) 836, Battle Creek (C. & G. T. R. R.) 823, (M. C. R. R.) 818, Bedford (M. C. R. R.) 807, Augusta (M. C. R. R.) 789, Galesburg (M. C. R. R.) 788, Comstock (M. C. R. R.) 778, Kalamazoo (M. C. R. R.) 770, (G. R. & I. R. R.) 778, Cooper (G. R. & I. R. R.) 774, Travis (G. R. & I. R. R.) 746, Plainwell (G. R. & I. R. R.) 741, Alamo (M. C. R. R.) 764, Williams (M. C. R. R.) 759. If the Kalamazoo channel received the waters of the Imlay outlet during the earlier stage of the activity of the latter, as we are inclined to believe, further investigations will probably show a connection to exist by way of Cohoctah and Lapeer or west of the latter place. However, more detailed work will doubtless bring to light other lines of drainage and until such work is done no reliable prediction can be made. During the time of greatest activity of the Kalamazoo outlet when the edge of the Saginaw lobe occupied the position of the Charlotte moraine and that of the Michigan lobe was at the position of the Valparaiso moraine, the waters from the two opposing ice fronts north of Plainwell evidently came down by way of the Gun Lake branch. Later when the Saginaw lobe had retreated to the north side of the Thornapple River, the principal drainage must have been by way of the Thornapple and Gun Lake channel.

The Milford channel.—The only part of this channel as yet known is the wide valley occupied by the Huron River between Milford and Hamburg Junction. It has been suspected that this channel connected with the Kalamazoo outlet, but from what has

preceded it is evident that the westward extension of the Milford channel must be sought farther south. From the behavior of the rivers and the general character of the drainage it is suspected that the course of this channel lies westward along Portage Creek, a few miles north of Jackson, then southwestward by way of Homer, and thence down the St. Joseph River, joining the Kalamazoo at South Bend.

Reversal of Drainage.—The limited amount of study thus far given to the region has shown the existence of many interesting examples of stream piracy and reversed drainage. The writer has pointed out one of these in the case of Black River near Port Huron.[1] Several others can be readily pointed out on the accompanying map. It is evident that the region of southern Michigan offers excellent opportunity for physiographic study, and the legislature of the state could not perform a better service than to make a liberal appropriation to the geological survey for the purpose of putting this material in shape for the use of the public schools.

C. H. GORDON.

[1] JOUR. GEOL., Vol. V, 1897, p. 315.

NOTES ON SOME IGNEOUS, METAMORPHIC, AND SEDIMENTARY ROCKS OF THE COAST RANGES OF CALIFORNIA.[1]

The metabasalts and diabases of the Coast Ranges.—There are very abundant masses of greenish rocks in the Coast Ranges which are often massive, but sometimes form distinct breccias. The microscopic investigation of these rocks show them to be of igneous origin, and to largely represent old lavas. Many such rocks were supposed by Professor Whitney, the former state geologist of California, to be metamorphic sandstones. Dr. Becker, in his investigation of the quicksilver deposits[2] of the Pacific slope, regarded some of them as metamorphic sandstones, and gave such the name "pseudo-diabase" and "pseudo-diorite." In an investigation of the geology and petrography of Mt. Diablo,[3] I found that some of the so-called metamorphic sandstone of Whitney was true diabase and unquestionably of igneous origin. In this conclusion, Dr. Becker concurred. More recently Dr. Ransome,[4] in a study of the rocks at Pt. Bonita, California, found there similar rocks, which he called basalt and diabase. Still later, Ransome, in an investigation of the geology of Angel Island, found certain greenstones which he considered as allied to fourchite, although admitting that feldspar might have been present in the rock, as indicated by the great abundance of a zoisite-like mineral in some thin sections.

In 1897, in company with Mr. J. S. Diller, I visited Angel Island and collected there specimens of the so-called fourchite, and of other rocks. Some of these specimens show plenty of fresh plagioclase and there is therefore no doubt that some of

[1] The author, doubtless due to absence in the field, has been unable to read the proof of this article.

[2] Mon. XIII, U. S. Geol. Surv. [3] Bull. Geol. Soc. Am., Vol, II, pp. 383–414.

[4] Bull. Dept. Geol., University of California, Vol. I, pp. 71–114.

this greenstone is a feldspathic rock, and not a fourchite. However, if we suppose that the pyroxene in the specimen analyzed by Ransome be an ordinary aluminous augite, and that all the magnesia of the rock is in the augite, a calculation shows that the rock contained about 80 per cent. of augite, so that in this specimen the feldspar must have existed in small amount. The specimens from the Angel Island fourchite area which I examined have the structure and composition of a holocrystalline basalt in which the augite shows an idiomorphic tendency, as it often does in modern doleritic basalts. The Angel Island greenstone may, therefore, be called in part a metabasalt, and this term should likewise be extended to the basaltic rocks at Pt. Bonita, inasmuch as in all cases the basalts have undergone extensive metamorphism. A comparison of the analyses of the spheroidal basalt at Pt. Bonita, with that of the fourchite at Angel Island, and of other greenstones from other portions of the Coast Ranges,[1] brings out very clearly the similarity in composition of these greenstones at widely separated localities.

ANALYSES OF METABASALTS AND DIABASES FROM THE COAST RANGES.

<table>
<tr><th></th><th>I
Fourchite from Fourche Mt.</th><th>II
Fourchite from Angel Island</th><th>III
Diabase, Pt. Bonita</th><th>IV
Diabase, Pt. Bonita</th><th>V
Spheroidal basalt, Pt. Bonita</th></tr>
<tr><td>Silica</td><td>42.03</td><td>46.98</td><td>45.59</td><td>46.28</td><td>49.45</td></tr>
<tr><td>Alumina</td><td>13.60</td><td>17.07</td><td>20.99</td><td>12.96</td><td>17.58</td></tr>
<tr><td>Ferric oxide</td><td>7.55</td><td>1.85</td><td>2.49</td><td>4.67</td><td>3.41</td></tr>
<tr><td>Ferrous oxide</td><td>6.65</td><td>7.02</td><td>4.36</td><td>6.06</td><td>3.41</td></tr>
<tr><td>Lime</td><td>14.15</td><td>12.15</td><td>7.57</td><td>10.12</td><td>7.20</td></tr>
<tr><td>Magnesia</td><td>6.41</td><td>8.29</td><td>8.95</td><td>8.71</td><td>4.05</td></tr>
<tr><td>Potassa</td><td>.97</td><td>.53</td><td rowspan="2">4.89</td><td rowspan="2">3.75</td><td>1.57</td></tr>
<tr><td>Soda</td><td>1.83</td><td>2.54</td><td>5.83</td></tr>
<tr><td>Analyst</td><td>Brackett and Noyes</td><td>Ransome</td><td>Ransome</td><td>Ransome</td><td>Ransome</td></tr>
</table>

1. Fourchite from Fourche Mountain, Arkansas. (Ann. Rept. Geol. Surv., Arkansas, 1898, Vol. II, on "The Igneous Rocks of Arkansas," by J. Francis Williams, p. 108.) This

[1] See table of analyses.

rock is composed of 75 per cent. of augite and secondary material, probably leucoxene, with a highly altered ground mass.

2. Fourchite from Angel Island. (Bulletin Dept. of Geol. University of California, Vol. I, p. 231.) Ransome.

3 and 4. Diabase from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

5. Spheroidal basalt from Pt. Bonita. (4th Bulletin Dept. of Geol. University of California, Vol. I, p. 106.) Ransome.

	VI Epidiorite-Potrero	VII Pseudo-diabase Mt. St. Helena	VIII Pseudo, diabase, Sulphur Bank	IX Diabase, Mt. Diablo	X Diabase, Mt. Diablo
Silica	47.41	49.08	51.28	51.58	52.06
Alumina	16.03	14.68	15.05	14.99	14.34
Ferric oxide	2.66	1.95	2.41	2.04	2.11
Ferrous oxide	7.05	9.63	8.01	8.36	7.74
Lime	12.33	10.09	7.08	8.59	8.05
Magnesia	5.81	6.69	6.07	6.51	9.26
Potassa	4.47	0.20	0.12	0.31	0.73
Soda		4.60	4.43	3.08	1.74
Analyst	Palache	Melville	Melville	Melville	Melville

6. Epidiorite Potrero. (Bulletin of Geol. University of California, Vol. I, p. 177.) Palache.

7. Pseudo-diabase from near Mt. St. Helena. (Monograph XIII, U. S. G. S., Becker, Quicksilver Deposits, p. 98.)

8. Pseudo-diabase, Sulphur Bank. (Mon. XIII, p. 99.) Becker.

9 and 10. Diabase from Mt. Diablo. (Bulletin Geol. Soc. Am., Vol. II, p. 412.) Turner.

Serpentine.—There are very abundant areas of serpentine in the Coast Ranges, single masses often covering many square miles. The occurrence of serpentine was noted by the geologists who accompanied the Pacific Railroad exploration parties, and the first analysis of a California serpentine which I have found recorded, is that given by Professor Newberry, and is of a specimen collected at the Presidio at San Francisco. Later,

Professor Whitney, in the study of the Coast Ranges, came to the conclusion that the serpentine originated from the alteration of sediments. Dr. M. E. Wadsworth,[1] who studied the Whitney collection of rocks, however, subsequently described some of the serpentines and pyroxenites and peridotites from serpentine areas in California, as probably being igneous rocks. Professor Whitney, under whose supervision Dr. Wadsworth worked, does not appear to have objected to this.

When Dr. Becker undertook the investigation of the geology of the quicksilver districts, the difficulty of accounting for the great change in chemical composition of any sediment to a rock with the composition of serpentine was very apparent. However, he found evidence of such alteration in the sandstones of what is now known as the Franciscan or Golden Gate series. Some of these sandstones contain igneous material, derived undoubtedly from preëxisting igneous rocks or from volcanoes of the Golden Gate period, and some of this igneous material undoubtedly has formed some serpentine. Indeed, needles of serpentinoid material were noted eating their way into grains of quartz, and such evidence led Dr. Becker to conclude that considerable masses of serpentine were thus formed. He suggested that sufficient magnesia for such a metasomatic change might be derived from the micas of the granites which underlie the Coast Ranges. Dr. Becker[2] later (1893), however, regarded some of the serpentine masses described in the quicksilver monograph as being altered peridotites.

In my field work at Mt. Diablo I came to the conclusion that the serpentine there is of igneous origin, as I found traces of the original pyroxene and olivine of the peridotite from which the serpentine was derived at several points. Dr. Charles Palache, in his bulletin on the rocks of the Potrero, San Francisco, likewise concluded that the Potrero serpentine is of igneous origin, and Dr. Ransome treated the serpentine of Angel Island

[1] Lithological Studies. Memoirs Mus. Comp. Zoöl., Vol. XI, Pt. I, pp. 129, 132, 142 and 158. (See also general discussion of the origin of peridotite, pp. 189–192.)

[2] Mineral Resources of the U. S. for 1892, DAY, p. 144.

ANALYSES OF SERPENTINES FROM THE COAST RANGES.

	No. 223, Mt. Diablo	No. 176, Mt. Diablo	No. 222, Mt. Diablo	Presidio	No. 78 *b*, Sulphur Bank	No. 181, Mt. Diablo	No. 110, New Idria	No. 78 *e*, Sulphur Bank	Angel Island
Si_2O - - -	34.84	36.57	36.96	39.60	39.64	40.50	41.54	41.86	42.06
Cr_2O_3 - -	0.68	0.33	0.78	.20	0.29	0.41	....	0.24	....
Al_2O_3 - -	0.42	0.95	0.39	1.94	1.30	0.78	2.48	0.69	2.72
Fe_2O_3 - -	6.08	7.29	5.00	....	....	4.01	....	....	
FeO - - -	1.85	0.37	2.34	8.45	7.76	2.04	1.37	4.15	2.88
MnO - -	0.01	0.10	0.09		0.12	0.13	....	0.20	....
NiO - - -	Trace	0.31	Trace	....	0.33	0.11	0.04	Trace	....
CaO - -	7.02	0.14	3.81	....	....	0.39	....	....	....
MgO - - -	30.74	40.27	33.84	36.90	37.13	37.43	40.42	38.63	39.53
K_2O - -	0.07	Trace	0.14	....	....	0.16	....	....	....
NaO - - -	0.42	0.31	0.34	....	....	0.28	....	....	....
H_2O above 100° C	15.72	12.43	14.02	12.91	12.91	10.94	14.17	14.16	12.04
Analyst - -	Melville	Melville	Melville	Easter	Melville	Melville	Melville	Melville	Ransome

Analyses Nos. 223, 222 176, and 181, from Mt. Diablo are taken from Bull. Geol. Society of America, Vol. II, pp. 383–414. The analyses of the Presidio rock is by J. D. Easter, and is from a report by Professor J. S. Newberry, in the Pacific Railroad report, Vol. VI, Part II, p. 11.

Analyses Nos. 78 *b*, 78 *e*, and 110 are taken from Monograph XIII, U. S. Geol. Surv., by G. F. Becker.

The analyses from Angel Island are taken from the Bulletin Department of Geology, University of California, Vol. I. p. 106.

as a metamorphosed igneous rock. The Angel Island rock was, however, considered as possibly being derived chiefly from diallage, but the analysis given shows clearly that no such derivation is possible. The table of analyses given below indicates how uniform in chemical composition the serpentines of the Coast Ranges are, and also that olivine or rhombic pyroxine must have been a prominent constituent of all of the original rocks from which the serpentines analyzed were derived.

The Franciscan or Golden Gate formation.—The metamorphic rocks of the Coast Ranges, and the associated cherts, sandstones, and shales, were formerly considered as of the age of the Knoxville beds; that is, lower Cretaceous. The more highly metamorphosed of these rocks are green amphibolite-schists, blue amphibolite-schists (glaucophane-schists), mica-schists, chlorite-schists, and various other schistose rocks. In my bulletin on Mt. Diablo, it was assumed that the red cherts or jaspers were silicified shales, and that these jaspers, together with the sandstones and schists associated with them, were the result of regional metamorphism of the Knoxville formation. Since that time it has apparently been shown, chiefly by Dr. H. W. Fairbanks, that these jaspers, associated sandstones, and schists are older than the Knoxville beds, and probably of Jurassic age. The best description of this series of rocks is that by Professor A. C. Lawson in his "Sketch of the Geology of the San Francisco Peninsula."[1]

One of the most interesting rocks of the series is the blue amphibole-schist, which is often found in croppings in or near serpentine masses. The blue amphibole is perhaps in part glaucophane, and these rocks have, therefore, generally been called glaucophane-schists. Dr. Ransome, in his study of the geology of Angel Island, found these schists at so many points on the border of serpentine masses that he concluded that they were contact metamorphic rocks. Professor Lawson, in the paper above referred to, considered the schists rich in amphibole to be metamorphosed volcanic material, but ascribed their origin, in

[1] Fifteenth Ann. Rept. U. S. Geol. Surv.

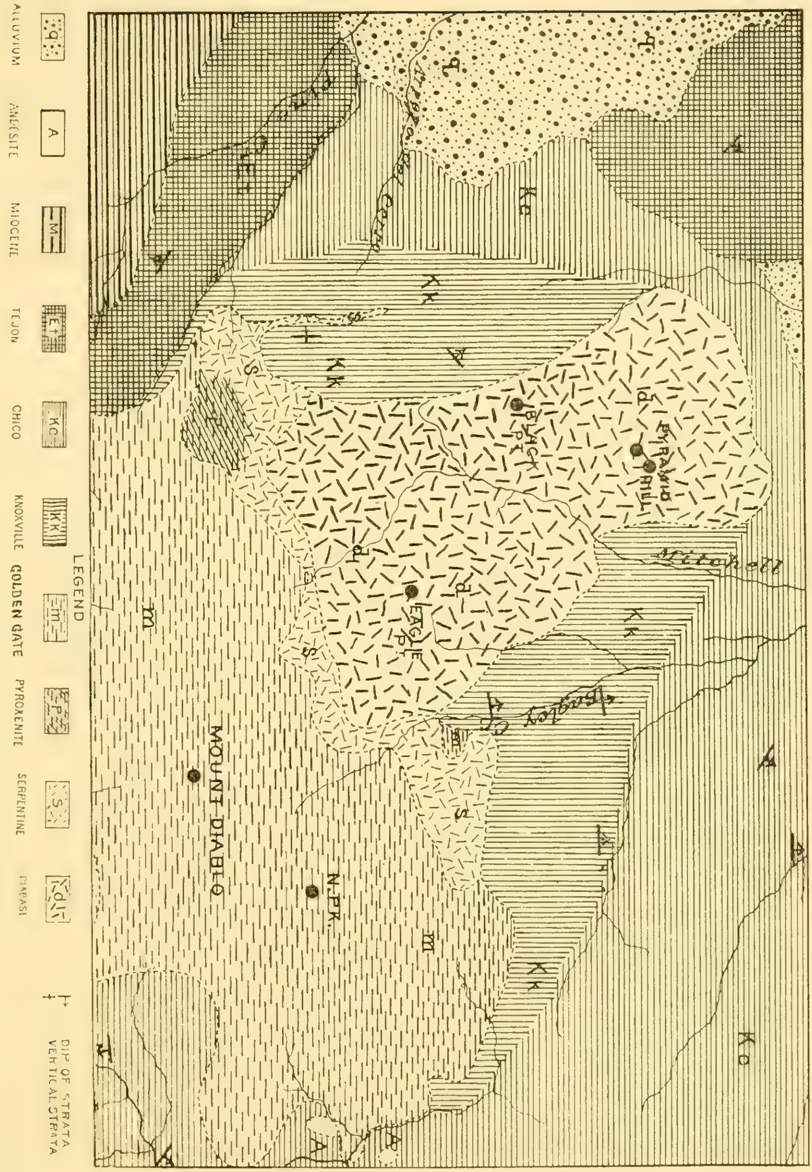
part at least, to contact metamorphism, and not regional metamorphism, believing that Dr. Ransome has established this in his bulletin on Angel Island. Professor Lawson seems to me to state the case very fairly. He writes as follows:

"In some few cases the schist areas have a very definite relation to dikes and laccolitic lenses of serpentine, and some of the most highly altered phases of schist that have been found, both of the micaceous and the blue amphibole varieties, have been taken from the immediate contact with the serpentine. In these cases there seems to be little doubt that we are dealing with a contact zone. In other cases, however, we have the immediate contact of serpentine and sandstone well exposed with no perceptible development of schist at the contact and little alteration of any kind appreciable to the unaided eye beyond a narrow zone of hornfels. It seems clear, therefore, that the metamorphic action of intrusive peridotite upon the rocks which it invades is not uniform, and the conditions which determine in some cases a maximum and in some cases a minimum of metamorphism are not yet known."

The point Lawson makes, that serpentine in many cases has merely hardened the sediments into which it is intruded and has not metamorphosed them, is perhaps of vital importance in discussing the origin of these schists. In the case of granitic intrusions into sediments, as everybody knows, there is always a zone of metamorphism all around the mass, and the conclusion that the granitic rock has caused this metamorphism appears to be absolutely demonstrated. When, therefore, we have an igneous intrusion which is bordered by schists on one side and by little altered sediments on the other, and if we know the latter to be older than the igneous mass and intruded by it, it is difficult to imagine conditions which cause such variable effects if we ascribe the formation of the schists to contact metamorphism. Such a case may be finely seen at Mt. Diablo. Here a dike of serpentine about 6.6^{km} long and 800^{m} wide extends in an east and west direction from the north flank of the mountain to near the east fork of Pine Creek. (See the geological sketch map of

Mt. Diablo.) On the south, this serpentine dike is flanked chiefly by the rocks of the Golden Gate series. On the north, at its east end, it is in contact with the shales of the Knoxville formation, and also, at its west end, in the upper drainage of the Arroyo del Cerro. At both points, it has effected no appreciable alteration of the Knoxville formation. In the Arroyo del Cerro drainage, the intrusive nature of this serpentine is beyond all question. The shales here stand nearly vertically with a strike in the neighborhood of the serpentine, approximately north and south, and a narrow apophysis of the main dike extends north into these shales for nearly one mile. This dike is cut by the Arroyo del Cerro and smaller streams, and in the ravines of these streams the dike nature of this serpentine apophysis can be clearly seen. The accompanying geological map shows the serpentine dike here described with the narrow apophysis extending north into the Knoxville shales. The area of the Golden Gate formation (*m*) in reality includes considerable masses of igneous rocks, chiefly metabasalt and serpentine. Thus the north peak is composed of a metabasalt which is said by Ransome to exhibit a spheroidal structure.

The Golden Gate series at Mt. Diablo, as elsewhere, however contains large amounts of igneous material which would more readily undergo recrystallization than the argillaceous and siliceous material of the Knoxville formation. It seems, therefore, possible that any contact metamorphism which the original peridotite of the serpentine dike might exert, would show more pronounced effects on the sediments of the Franciscan or Golden Gate series than on the material of the Knoxville formation. In addition to the large dike there are smaller masses of serpentine at various points along the flanks of the mountain. Glaucophane-schist is found near some of these serpentine croppings; in some cases exactly alongside of them; in other cases, it is not at the contact, but forms isolated croppings along with green amphibole-schists and micaceous schists. It would be unwise to insist that these schists have not resulted from the metamorphism of igneous material, by intrusive igneous masses, but it



GEOLOGIC MAP OF THE VICINITY OF MOUNT DIABLO, CALIFORNIA.

appears to me, in view of the foregoing facts, that it is yet to be demonstrated that these schists are the result of contact metamorphism of the peridotite intrusions. In any case, it seems clear that the glaucophane-schists and the green amphibole, garnet, and micaceous schists associated with them, are all caused by the same kind of metamorphism.

An investigation of the geology of the Bidwell Bar quadrangle, in the northern Sierra Nevada, has brought to light the existence of large areas of magnesian schists, associated with serpentine. These magnesian schists are composed of talc, chlorite, and various amphiboles, among which are prominent certain colorless amphiboles approximating to edenite and gedrite in composition. The microscopic investigation of these rocks clearly shows that these magnesian schists are alteration products of rocks of the same general nature as those which form the serpentine; that is to say, of rocks of the pyroxenite-peridotite family. The serpentine itself, no doubt, was largely formed from those masses rich in olive or rhombic pyroxene, and the various schists from aluminous pyroxenic facies of the magma. Many of these masses form croppings in and along serpentine masses, but they also form isolated areas of considerable extent. To conclude that any of these schists were formed by contact metamorphism would certainly in this case be erroneous, for not only can their composition be accounted for by supposing them to be alteration products of various pyroxenes, but their formation from these pyroxenes can in many cases be seen in the thin sections of the rocks.

If, as thought by Fairbanks, the Franciscan or Golden Gate series is older than the Knoxville, its generally hardened and altered character may have been the result of a pre-Knoxville metamorphism; for the beds, which have been determined as Knoxville, are nowhere much altered. It may then be advanced as a working hypothesis that the entire schist series of the Golden Gate formation was formed before the deposition of the Knoxville, and before the intrusion of at least some of the serpentine. If this be true, pebbles of some of these schists should

be found in the conglomerates of the Knoxville formation. Such conglomerates were observed at Knoxville, in Napa county. When making a geological map of the Knoxville quicksilver district for Dr. Becker, I collected some pebbles from these conglomerates, and later published[1] a few notes concerning them. As the characteristic fossil of the Knoxville formation (Aucella) occurs in this conglomerate, there can be no doubt concerning its age. The pebbles are of various porphyries, including soda-syenite porphyry and augitic porphyries and fine cherty pebbles, indistinguishable from the rocks called phthanites by Becker, radiolarian cherts by Lawson, and jaspers by Whitney and Fairbanks. A thorough investigation of these conglomerates will, perhaps, bring to light pebbles of some of these schists, the origin of which is ascribed to contact metamorphism and thus make certain their pre-Knoxville age. This being established, it would at least be certain that these rocks, if formed by contact metamorphism, were not formed by the serpentines which are found intruded into the Knoxville formation.

To the southeast of Coulterville,[2] in Mariposa county, and at other points, there are dikes of soda-feldspar, which are frequently intruded along the contact of serpentine masses with other rocks. These soda-syenite dikes, where altered, often contain blue amphibole in varying amount. Some of this may be primary, but part of it is secondary, The formation of glaucophane-schists (soda-amphibole) from crushed rocks containing much albite (soda-feldspar) seems quite possible. This is heightened by the finding by Ransome of white bunches composed of albite, in association with the glaucophane-schists on Angel Island. The suggestion of such an origin for the glaucophane-schists of the Coast Ranges should not, however, be taken too seriously.

Fossils being rare in the Golden Gate formation, all localities where remains have been found are worthy of note. About one mile (1.6 klms.) northeast of the summit of the north peak

[1] Am. Geol., Vol. XI, May 1893, p. 316.

[2] 17th Ann. Rept., U. S. G. S., Pt. I, p. 729.

of Mt. Diablo, in a ravine above the house of young Ben Dixen, fossils were found by Mr. F. M. Anderson, a student at the University of California, to whom I am indebted for the information. In company with Dr. Merriam, I visited this locality in 1897. We found more fossils there in thin, shaly layers in the hardened sandstone of the Golden Gate formation in a ravine above the house. This ravine heads just northeast of the north peak, and has a northeasterly course to about the fossil locality, where it turns sharply to the east. We collected some lamellibranchs here, which were not, however, specifically determinable. The sandstone is much intersected with fractures and can be readily broken out. This locality will probably afford more material, if carefully worked. Dr. T. W. Stanton, who saw Mr. Anderson's fossils, thought that the forms belonged to the *Cyprinidæ* or *Veneridæ*, but was unable to express a positive opinion concerning them.

The San Pablo formation. — At Kirker Pass,[1] north of the Mt. Diablo, south of the mountain at the Railroad Ranch reservoir, and at Corral Hollow, there are beds containing large amounts of volcanic detritus, as well as fossil shells and plant remains. The beds at Kirker Pass and Corral Hollow were first made known through the investigations of the State Geological Survey, under Professor Whitney. At a later date I visited the three localities above named and collected fossil plant remains at all of them, and fossil shells at two of them. The plant remains were studied chiefly by Professor Lesquereux, who assigned some of them to the Pliocene and others to the Miocene. The fossil shells were examined by Dr. Dall, who considered them to indicate a Pliocene age. Dr. Gabb had previously collected quite a series of fossil shells at Kirker Pass, and on that basis called the beds Pliocene.

In October 1897, in company with Dr. J. C. Merriam, I again visited Kirker Pass, and we collected there fossil shells and

[1] This pass is named after a Mr. Kirkwood, but the name Kirker having been used in geological literature for a long period, it is perhaps inadvisable to change the name to Kirkwood Pass.

plant remains, and I am indebted to Dr. Merriam for the following list of marine fossils from the Kirker Pass locality:

Fossils from San Pablo formation near Kirker Pass, north of Mt. Diablo, Contra Costa county, California. Collected by Gabb, Turner, and Merriam.

1. *Astrodapsis whitneyi* Rémond.
2. *Astrodapsis tumidus* (?) Rémond.
3. *Pseudocardium gabbi* Rémond.
4. *Ostrea Bourgeosii* Rémond.
5. *Ostrea titan* Rémond.
6. *Pecten pabloensis* Con.
7. *Pecten* (*Liropecten*) *crassicardo* Con.
8. *Cyrena californica* Gabb.
9. *Tapes staminea* Con.
10. *Tapes staleyi* (?) Gabb.
11. *Dosinia ponderosa* Gray.
12. *Gari alata* Gabb.
13. *Standella falcata* Gld.
14. *Saxidomus squalibus* Dash.
15. *Cardium blandium*.
16. *Macoma nasuta* (?) Con.
17. *Solen* sp.
18. *Mytilus* sp.
19. *Modiola* sp.
20. *Zirphœa* sp.
21. *Littorina remondi* Gabb.
22. *Littorina planaxis* Phil.
23. *Trophon ponderosum* Gabb.
24. *Ranella californica* Hds.
25. *Purpura saxicola* Val.
26. *Lunatia lewisii* Gld.
27. *Crypta grandis* Midd.
28. *Crepidula adunca* Sby.
29. *Calliostoma* n. sp. (?) Merriam.
30. *Ocinebra lurida* (?) Midd.
31. *Trochita filosa* Gabb.
32. *Trochita* n. sp. Merriam.
33. *Olivella boetica* Cpr.
34. *Bittium asperum* Cpr.
35. *Fusus* Gld.
36. *Purpura canaliculata* Duc.

This list contains 5 forms belonging to the Miocene, 2 (5?) forms belonging to the Merced formation, and 11 forms found elsewhere in the San Pablo formation.

There are 17 extinct and 14 living species, and the formation may, therefore, be regarded as of lower Pliocene age, on the basis of the ratio of the living and fossil forms.

In a recent paper,[1] on the Neocene sea-urchins, Dr. Merriam refers to the beds at Kirker Pass and similar beds at other points containing tuffs and volcanic ashes, as the "San Pablo formation." He considers the sea-urchins, belonging to the genus Astrodapsis, as particularly characteristic of this formation, inasmuch as he has not found them outside of it, and his information concerning the formations covers other localities besides those mentioned in this paper. This series of strata will then hereafter be spoken of as the San Pablo formation. In the bulletin, above referred to, Dr. Merriam concludes that this formation is of Middle Neocene age, including the top of the Miocene, and the base of the Pliocene. In my bulletin on Mt. Diablo, I called attention to the similarity of the plant forms in the San Pablo formation of the region about Mt. Diablo with the plant remains of the Auriferous gravels formation of the Sierra Nevada. The collections of the plant forms from the Coast Ranges are not sufficient to narrowly correlate the plant remains from the two regions, but it is clear that the marine fossil shells of the San Pablo formation furnish a more certain criterion for determining the exact horizon of the formation, than do the plant remains.

When the plant forms of the San Pablo formation have been collected in greater number and thoroughly studied a comparison can then be made between the floras of the Auriferous gravel series, and of the San Pablo formation, and the age of the auriferous gravels decided on that basis. As pointed out in an article on the Auriferous gravels,[2] it is certain that the fossil leaves collected from different localities in the Sierra

[1] Bull. Dept. Geol. Univ. of California, Vol. II, p. 116.

[2] American Geologist, Vol. XV, June 1895.

Nevada from the Auriferous gravels formation represent different horizons; nevertheless, no distinction has been made thus far by the palæobotanists, who have examined the different collections. It is, therefore, probable that, when studied, certain of these localities will be found to furnish a flora similar to that of the San Pablo formation, and other localities will furnish floras of a somewhat older date. In general, in recent years, the fossil plant remains of the auriferous gravels have been called Upper Miocene. It is more than likely that some of these localities are of Pliocene age. There is published herewith, a section of the San Pablo formation at Kirker Pass, north of

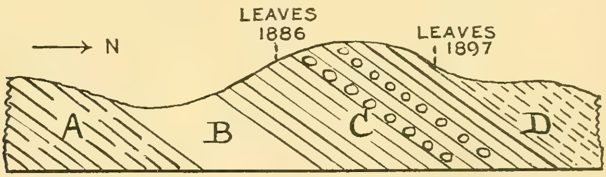


FIG. 1.—Section of the San Pablo formation on the Hyde Ranch, north of Mt. Diablo. The horizontal extent of the section is about 600 meters. The section, however, does not necessarily include the top or the base of the formation at this point. *A* = White shales and rhyolitic tuff; *B* = Fossiliferous sandstone; *C* = Andesitic tuff, sandstone, and conglomerate; *D* = Shale and pumice.

Mount Diablo. The horizontal extent of the beds shown in the section is 600 meters. The beds dip uniformly to the north at an angle of about 35° and thus have a thickness normal to the bedding of about 350 meters, or about 1150 feet. The section given above (Fig. 1) is drawn without reference to scale, merely to show the relations of the different members of the formation. The basal portion (*A*) of the section is composed of fine-grained white shales, and volcanic detritus, which Dr. Merriam has noted at other localities in the formation, and he regards this as its base. An optical examination of volcanic glass which forms certain layers in these white shales, shows the glass to be of rhyolitic composition. There is given below an analysis, No. 399, of a specimen of this glass. This analysis shows that the rhyolite has undergone leaching, having lost both alkali and silica, as is

very frequently the case with layers of volcanic glass and pumice. Overlying this basal volcanic series are some sandstone beds (*B*), which have offered the majority of the marine fossil shells from this locality. Lying upon fossiliferous sandstones are a set of blue beds (*C*), composed of volcanic conglomerate, tuff and sandstone. The tuffs and volcanic conglomerates are derived from andesite, containing hornblende and pyroxene. These andesitic tuff beds contain abundant silicified wood, and the first list of fossil leaves given below collected in 1886, came from a fine layer in this tuff series.

These leaves were studied by Lesquereux, who published a list of the species identified in the proceedings of the U. S. National Museum (Vol. XI, 1889, p. 35), as follows.

Fossil leaves from the San Pablo formation on the Hyde Ranch, collected in 1886.

Diospyros virginiana 1, var. turneri, Lx.
Magnolia californica Lx.
Laurus, cf. *canariensis* Heer.
Virburnum, cf. *rugosus* Pers.
Vitis, sp. (?).

These are considered to be probably Pliocene, although on page 11 of the same publication, the same collection is referred to the Upper Miocene. These leaves come from a fine layer in the blue andesitic sandstones which form a higher horizon than the bed which afforded the most of the fossil shells given in the previous list by Dr. Merriam.

The leaves collected in October 1897, came from a bed conformably overlying the blue andesitic sandstones, and underlying the volcanic pumice represented by specimens 345 (Series D). Immediately underlying the leaf layer, is a light colored layer, containing specks of pumice in which are fossil shells. One of these, is an Astrodapsis, as determined by Dr. Merriam, which is considered as characteristic of the San Pablo formation. This second set of leaves came from a higher horizon of the San Pablo formation than those collected in 1886. The leaves collected in 1897 were referred to Professor F. H. Knowlton

of the National Museum, who reports as follows concerning them :

Six species of plants are represented :

Fern, probably *Pteris*, but very fragmentary.
Populus, female Catkin.
Alnus, fruits and leaves.
Castanea, sp. leaf.
Vaccinum, sp. single small leaf.
Arbutus, sp. Numerous well-preserved leaves and fragments.

I have not been able to identify any of the above mentioned material with anything from California. The forms all have a very modern aspect, the more abundant being the Arbutus, which is close to the living form.

As to the age, I do not think there can be any doubt about their being Pliocene. They certainly cannot be older.

The conclusion of Professor Knowlton that the plant remains in 1897 are certainly not older than Pliocene, would not appear to conflict with the conclusion of Merriam as to the Middle Neocene age of the formation as a whole, inasmuch as these leaves came from near the top of the formation, as exposed near Kirker Pass. Overlying the plant remains above noted, are some layers of volcanic pumice (*D*), of which specimens were collected. An examination of this material under the microscope shows that it has been much altered by infiltrating waters, but that the glass has a rhyolitic composition, as indicated by its low index of refraction. A chemical analysis of one specimen, No. 345, shows, as does the analysis of No. 399, that the pumice has undergone leaching, resulting in a loss of silica and alkali. All of the plant remains obtained by myself at Kirker Pass came from the Hyde Ranch, and were collected in a field west of the road from Cornwall to Summersville. The locality of 1897, is on the north slope of a low hill, and about 430 meters south of the house of George South.

The San Pablo formation, at Corral Hollow, has afforded nineteen species of fossil plants. A few of which have been identified in the Auriferous gravels flora. The plant beds at Corral Hollow, from which the specimens came which I collected, underlie andesitic tuffs, and conglomerates, which are

quite like those of the San Pablo formation, in the Mount Diablo quadrangle. It is, therefore, likely that the Corral Hollow plant remains represent a somewhat older horizon than those collected near Kirker Pass.

ANALYSES OF RHYOLITIC TUFF FROM THE SAN PABLO FORMATION, BY WILLIAM VALENTINE.

	No. 339. Near base of San Pablo	No. 345. Near top of San Pablo
SiO_2	63.28	63.28
CaO	1.90	1.18
K_2O	2.44	0.78
Na_2O	1.82	0.56

The Merced formation of Lawson,[1] which has been referred to, is probably younger than the San Pablo and of Upper Pliocene age. The Merced formation is named from Merced Lake, in the vicinity of which the beds are extensively developed. It is probably identical with the Wild Cat series of Humbolt county, described by Lawson,[2] in which case the latter name should be dropped. As pointed out by Lindgren,[3] the correlation by Lawson on the Merced series with the Auriferous gravels formation is probably incorrect. It is far more likely that the Auriferous gravels series is in part contemporaneous with the San Pablo formation, and in part older than that formation.

H. W. TURNER.

[1] Bull. Dept. Geol. University of California, Vol. I, pp. 142–149.

[2] Bull. Dept. Geol. University of California, Vol. I, pp. 255–263.

[3] JOUR. GEOL., Vol. IV, pp. 904, 905.

Studies for Students.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

II. AMPHIBIA.

THE *Amphibia* may be described as forms that live a portion of their lives, at least, in the water or in a condition fitted for an aquatic existence; the latter statement is necessary from the fact that some forms never live in the water, but develop external gills such as are found in the forms which do pass the larval stage as aquatic forms. All amphibians pass through a metamorphosis in which the external gills of the immature forms are lost and lungs developed. The skull presents some peculiarities; the whole base of the cranial region is covered by a large presphenoid bone that extends far forward as well as backward. In the more highly developed types of the vertebrates this bone occupies a minor position anterior to the basioccipital. In many of the more primitive forms of the amphibians the bones of the cranial region are largely cartilaginous; the extremities of the long bones of the limbs are without the epiphyses, or separate ossifications, that are found in the mammals, and the ribs are attached each to a vertebra instead of intervertebrally as in the higher forms.

That the *Amphibia* were derived from the *Pisces* is without question, but from what branch of the piscine stem they were developed has been the subject of much discussion. For a long time they were supposed to be derived from the *Dipnoans*, and from forms that were very close to the existing genera of the order. This idea is still supported by Haeckel (*Systematische Phylogenie der Wirbelthiere*; Berlin, 1895). In discussing the question, Baur said (The Stegocephali: a phylogenetic study;

Anatomischer Anzeiger, Band XI, Nr. 22, 1896, p. 659) "That the *Stegocephali* (the most primitive of the amphibia) did take their origin from a group of fishes is evident. The question to examine is: Which was this group?"

"In the Devonian preceding the Carboniferous, where the *Stegocephali* first appear, we have the following groups of fishes: The *Elasmobranchii* — including the *Holocephali* — *Ostracodermi*, *Dipnoi*, *Crossopterygii* and *Chondrostei* (this last group corresponds to the *Actinopterygii* of the present studies). The *Elasmobranchii* have no dermal ossifications in the skull, they are therefore out of the question; the *Ostracodermi* have, of course, nothing to do with the *Stegocephali;* we also can exclude the *Chondrostei* represented by *Cheirolepsis*. Only the *Dipnoi* and the *Crossopterygii* remain.

The dentition of the *Dipnoi* is already so much specialized in the Devonian, that it is impossible to derive the *Stegocephali* from them. We have now to consider the *Crossopterygians*. The *Crossopterygii* were established by Huxley, in 1861, to contain the living *Polypteridæ* of Africa and the extinct *Holoptychidæ*, *Rhizodontidæ*, and *Osteolepidæ*, having lobate paired fins with an endoskeletal axis, more or less fringed with dermal rays. The *Crossopterygii* are the most typical fishes of the Devonian. There is no difficulty in homologizing the premaxillaries, nasals, frontals, parietals, prefrontals, and postfrontals in the *Crossopterygii* and the *Stegocephali*." Here the author proceeds to prove from the course of the grooves upon the skulls of certain of the more primitive of the fishes and the amphibians, which mark the course of the sensory tracts of nerves in the living form, the homology of the skull bones of the two groups and the close connection that exists between them.

In a further discussion of the homology of the ribs he concludes that the "ribs of the oldest *Batrachia*, the *Stegocephali*, are not homologous with the ribs of the *Dipnoi*; therefore the *Dipnoi* cannot be the ancestors of the *Stegocephali*," and "the *Batrachia* must have developed from the *Crossopterygii*."

The *Amphibia* may be classified as follows:

Class, AMPHIBIA.
Order, *Labyrinthodontia.*
Suborder, *Branchiosauria.*
Microsauria.
Aistopoda.
Labyrinthodonta vera.
a, *Embolerimi.*
b, *Rachitomi.*
c, *Labyrinthodonti.*
Order, *Coecilia.*
Caudata (*Urodela*).
Suborder, *Salamandrina.*
Icthyoidea.
Order, *Ecaudata* (*Anura*).
Suborder, *Arcifera.*
Firmisterna.
Aglossa.

It is with the first of these orders that the student of palæontology is the most concerned, as they were the predominant forms of life during the Carboniferous time and even during the first part of the Mesozoic. The other orders did not assume any importance before the beginning of the Tertiary, and only one of them, the *Caudata*, appeared as early as the Cretaceous.

The earliest trace of amphibians is found in the Devonian rocks of Warren county, in Pennsylvania, and consists of tracks of some large labyrinthodont that Marsh has called *Thinopus antiquus* (*Am. Jour. Sci.*, 1896). No other trace of the *Amphibia* has been found in rocks earlier than the Carboniferous, but with the appearance of that time a large number of forms were developed that in the variety of their forms and the degree of their specializations rivaled the development of the reptiles of later times. To this large group of semi-aquatic forms Huxley gave the name *Labyrinthodonta* in 1863; five years later Cope gave the name *Stegocephali* to the same group. The latter name is used the most commonly in this country.

In external appearance the *Labyrinthodontia* were very similar to the existing tailed amphibians, the body was long in some cases and in others more stout and heavier; the skin was naked,

but in most cases, on the ventral surface, at least, protected by the development of small dermal ossicles of bone; the legs were in most of the forms rather short and weak, and in some cases were entirely atrophied as in the recent snakes; the bones of the more primitive forms were quite largely cartilaginous, the carpus and the tarsus of some forms being almost entirely so, and even the long bones of the limbs and the bones of the skull were incompletely ossified; the skull was completely roofed over by dermal bones developed in the skin of the head, leaving only five openings in the skull, the two nostrils, the orbits, and the pineal foramen, the last a single opening on the upper surface of the skull. The teeth of most of the forms, and of the more highly developed forms of the Trias especially, are notable for the peculiar infolding of the enamel, giving the internal structure of the tooth a most complicated appearance.

The structure of the spinal column in the various forms is of especial interest, as it parallels in the first stages the history of the spinal column of the fishes and takes the process a few steps farther. In all of the *Labyrinthodontia* the notochord is to a greater or less extent persistent. In the simplest of the *Amphibia* the chord is very large and the vertebræ are represented by small plates arranged in pairs on the upper and lower surface of the chord; to these plates are attached the spinuous processes and the hæmal arches that protect respectively the spinal chord and the nutrient arteries (in the amphibians the hæmal arches are complete only in the caudal region). The next stage in the development of the column is the union of the plates, on the upper and the lower side of the chord, to form a complete cylinder that incloses the chord. The cylinder is of equal bore throughout and does not constrict the chord or tend to divide it up into segments. These two conditions are found only in the most simple of the amphibians and are well illustrated in the immature and mature forms of the *Branchiosauria* (Fig. 1, *A*). The next step is the thickening of the walls of the middle portion of the cylinders that surround the notochord so that the bore is very small at the center, while at the anterior

and the posterior ends the bore is still full size; this tends to divide the notochord at the middle of each vertebra and to leave intervertebral segments. This condition of the vertebræ, with deep cups at each end, is called "biconcave." It is the same condition that is found in the primitive reptiles, and the closing of the notochordal canal and the filling up of either the anterior or the posterior cups of the vertebra would complete the development of the highest type of the reptilian vertebra. (Fig. 1, *B*.)

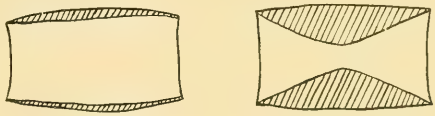


FIG. 1.—*A* Section of Branchiosaurian vertebræ showing size of notochordal canal; *B* Section of microsaurian vertebræ showing contraction of notochordal canal.

Another type of vertebræ that was developed by the amphibians seems to be somewhat more primitive than the last described, and also to be somewhat off the line of direct development. There were four distinct pieces, an upper, that supported the spinuous process, a pair, of small size, that stood on each side of the notochord, the pleura-centra, and a crescent shaped piece on the lower side, the intercentrum, that occupies the position of the plate supporting the hæmal arch in the simpler vertebræ. Upon the condition of these four pieces were established the divisions of the suborder *Labyrinthodonta vera*. When the pieces are all separate and in the condition described above, the forms are called rachitomous; the two lateral pieces may fuse and form a ring around the notochord, and at the same time the intercentrum develop from a crescent-shaped piece into a perfect ring, so that each vertebra is represented by two complete rings, this is the embolomerous stage; in the third condition the four pieces fuse to form a solid vertebra; this is most common in the caudal region and may be present there, while in the anterior portion of the column the

four original pieces are still separate. This is the stereospondylus condition (Fig. 2).

Another line of development that is quite closely connected with the geological history of the animals is the development of

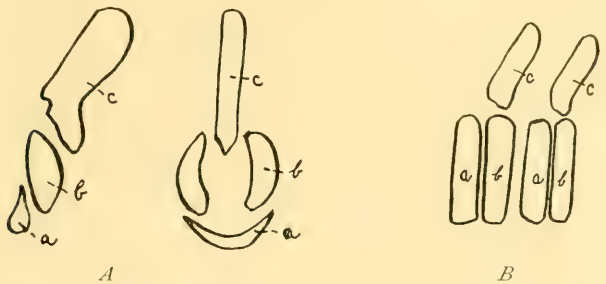


FIG. 2.—*A* Rachitomous vertebra. *B* Embolomerous vertebra. *a* Intercentrum; *b* Pleurocentrum; *c* Neural spine.

the shoulder girdle. In the more primitive forms, especially the *Branchiosauria* of the Permian, the bones of the shoulder region were largely cartilaginous and were small in size; as we progress through the Carboniferous and into the Triassic time the bones become larger and firmer, until in the latest of the Triassic forms they form a close dermal armor over the underside of the thoracic cavity. In the majority of the forms there is developed in the skin of the abdomen and the lower side of the legs as well, a large number of small bony ossicles that served as a protection for the posterior part of the body. The history of these is also closely connected with the geological progress of the animal; in the earliest forms the ossicles are small and numerous; as the forms progressed the ossicles became larger and less numerous.

BRANCHIOSAURIA.—This is the most primitive group of the *Amphibia*. The forms were all small and salamandriform; there was a short tail, and the limbs were short and weak. The vertebræ in the adult form were barrel-shaped as already described and in the immature form composed of two separate pieces, an upper and a lower. There was no plication of the enamel of

the teeth as in the more advanced forms. The bones were largely cartilaginous, the tarsus and carpus and the bones of the occipital portion of the skull entirely so. The ventral surface of the body was protected by a large number of dermal scutes.

Most of these forms are known from the Rothliegende of Germany, but specimens have been found from the same horizon and from the Upper Carboniferous of France and Ohio; from the German region a very large number of forms have been taken in the most excellent state of preservation so that it has been possible to study not only the adult forms, but the young stages as well and to make out the various steps in the metamorphosis of the individual. Credner studied a large series of forms from about 30^{mm} to 120^{mm}, and made out all the stages of development, the growth of the external gills, their loss, and the assumption of the adult form.

Branchiosaurus is the best known genus of the suborder and a description of it may serve as an illustration of the whole group. The head was comparatively large and rounded in front; the edges of both jaws were lined with numerous small, conical teeth; the skull was completely roofed by dermal bones, and the surface of these bones show a very strong sculpture. The condition of the vertebræ, the carpus and tarsus, and the bones of the occipital region was as already described; the limb bones were cartilaginous at the extremities. The eyes were rather large and were protected by bony plates developed in the sclerotic coat, the "sclerotic plates." The whole animal must have presented much the same appearance as one of the modern salamanders and had, probably, much the same habits, never going any great distance from the water.

Melanerpeton, *Apateon*, and *Pelosaurus* from the same locality and horizon as the *Branchiosaurus*, were very similar in appearance, differing only in minor skeletal characters.

Protriton is a form described from the Rothliegende of Autun, in France, and is regarded by some as identical with the early stage of *Branchiosaurus* as it has the external gills and other characters of the larval forms of that genus.

Amphibamus and *Pelion* are from the Carboniferous beds of Ohio. In the first genus the body was rather long; the legs were short with the posterior pair somewhat the largest; the head was rather large and rounded; the teeth were numerous and set close together. *Pelion* had a rather shorter and broader head, the legs were longer and better developed.

MICROSAURIA.—These were in many ways the most highly developed of the *Labyrinthodontia;* the vertebræ, as already explained, approached more nearly the modern type of reptilian vertebræ than any of the group. Their advanced position is evidenced by other parts of the body as well as the vertebræ; all the bones of the body are more perfectly ossified; the bones of the skull are set more firmly together, and the limbs are longer and stronger so that the animal was able to raise the body from the ground, and must have possessed a considerable degree of agility. The carpus and tarsus were ossified, and there were well-developed claws on the feet. Many remains have been found in the trunks and stumps of fossil trees in the working of the quarries in the South Joggins coal region of Nova Scotia, showing that the animals were to some extent at least arboreal in their habits, and that they had reached a freedom of motion and a range of habitat far in advance of that of the other amphibians of the time. It is to this group that we must look, in all probability, for the direct ancestors of the reptiles. The name *Sauromorpha* has been given to the group in recognition of the close relation between it and the *Reptilia.*

Hylonomus and *Hylerpeton* are forms from the South Joggins quarries of Nova Scotia. They were rather elongate in form, with a lizard-like appearance. The vertebræ were well developed, and the whole body was covered with bony scutes instead of the ventral surface only as in most of the forms. The teeth were smooth at the base, but near the top the dentine was somewhat plicated. These were among the best developed of the amphibian forms. It is interesting to note the occurrence of the same genus, *Hylonomus,* in Nova Scotia and in Bohemia.

From the Carboniferous rocks of Ohio, near Linton, have

been taken a very large number of the *Microsauria*. Among the most common are *Tuditanus*, *Leptophractus*, *Colosteus*, *Osteocephalus*, and *Ptyonius*.

Tuditanus was rather small form with a short and broad head and the orbits located far forward. There seems to have been a lack of the dermal scutes on the ventral surface and their place was taken by three pectoral shields that exhibit a strong sculpture on the external face; they were the expanded clavicles and the interclavicle. The whole animal was about three to four inches long.

Colosteus reached a length of a foot in some cases. The form was elongate with rather short legs. There were three pectoral plates as in *Tuditanus* as well as a well-developed armor of fine scutes. The teeth were not of equal size, the anterior ones being much the larger.

Ptyonius exhibits a very high degree of specialization. The body was long and serpentiform, and the limbs had entirely disappeared so that the animal had reached the same stage of development as the modern snakes. One very peculiar thing is to be noticed about this form; the distal edges of the transverse processes and neural-spines were fluted or folded so that they present a fan-like appearance.

Leptophractus was by far the largest of the Ohio forms, having about the size of an alligator. Only portions of the skull are known but enough to show that the skull was rather elongate, and that the teeth had the dentine folded as in the true labyrinthodonts. Near the anterior end of the jaw there was a large caniniform tooth.

Osteocephalus resembled in some respects *Ptyonius*. The body was long and snake-like, and the skull was very acuminate. The anterior pair of limbs were absent or rudimentary, and the posterior pair were very short. The three pectoral plates found in most of these forms were absent in this one, and their place was taken by a profusion of slender bony rods that ran obliquely inward and forward covering the whole ventral surface. There were no dermal scutes as in the other forms.

The Carboniferous rocks of Nyran in Bohemia have yielded many forms belonging to the same group, among them are *Hyoplesion*, *Orthacosta*, *Microbrachis*, *Keraterpeton*, and *Urycordylus*.

Hyoplesion is quite similar in structure to *Hylonomus* of the Nova Scotian region, and is regarded by some authorities as synonymous with it.

The other forms do not present any striking peculiarities except *Urycordylus*, which has the same peculiar fluting sculpture of the ends of the transverse processes and the neural-spines as *Ptyonius* and *Osteocephalus* of North America.

Aistopoda.—This group was very similar in some respects to certain forms of the previous group. The limbs were entirely atrophied as in *Ptyonius;* in addition to this character the parietal and frontal bones were fused into one, and the ribs showed a very peculiar bifurcated condition near the distal end.

Dolichosoma from the Carboniferous rocks of Ireland and Bohemia was quite long, having as many as 150 vertebræ, a number equaled only among the snakes. The skull was small and tapered to a point in front, and there was no evidence of dermal armor.

Ophiderpeton from the Carboniferous of Ireland had a somewhat shorter and broader skull than *Dolichosoma*; the ventral surface of the body was covered with small scutes; the whole animal was about 40–50^{cm} long, and there were in the neighborhood of 100 vertebræ.

Phlegethonia and *Molgophis* are two forms from the same region in Ohio as the *Microsauria* mentioned. They have been considered as synonymous with *Dolichosoma*, which, if true, would indicate a peculiarly wide range for such a specialized form.

Labyrinthodonta Vera.—As before stated this group is made up of three subgroups, the *Rachitomi*, the *Embolerimi*, and the *Labyrinthodonti*. The first subgroup is found only in the United States.

Rachitomi.—In this division, as in the others of the same group, there were many very large forms. The skull was com-

pletely covered with thick and heavy membrane bones that showed a deep and intricate sculpture; the whole head was flattened and either very broad in proportion to its length or long and crocodilian in aspect; the base of the skull was in large part cartilaginous; the limbs were short but very strong, and there were five digits on each foot: the tail was of moderate length; the pelvic and pectoral girdles were strong and broad; the pelvis was peculiarly like that of the modern frog in many of the forms; the vertebræ were made of several distinct pieces as already described. The known forms of the group are almost entirely from the Permian rocks of Europe, the East Indies, and North America.

Archægosaurus from the Rothliegende of Germany was rather crocodilian in aspect; the head was long and slender and joined to a rather elongate body. In youth the animal was furnished with external gills as in the modern salamanders, which were probably shed when the animal reached maturity; the dentine of the teeth was arranged in a radial manner the first step towards the intricate folding of the enamel in the more advanced forms; the clavicles and the interclavicle were broad and strong covering to some extent the lower surface of the thorax.

Chelydosaurus from the Rothliegende of Bohemia was shorter than *Archægosaurus* with a broad head and large orbits; the dermal bones covering the head were sculptured in a peculiar radial fashion. Nearly every portion of the skeleton is known, and the preserved bones show that the animal was rather in advance of the majority of the forms of the time as they are almost entirely free from cartilage.

Discosaurus is a closely related form from the same horizon in the neighborhood of Dresden.

Actinodon and *Euchirosaurus* are from the lower Permian (Rothliegende) of France. The first was much like *Archægosaurus*, but the head was shorter and more triangular in outline; the length of the skull was about 18^{cm}. The second genus is less well known than the first, but is remarkable for the strength

and perfection of the limb bones, especially the articular surfaces which, as a general thing, are not well developed even in the recent amphibians.

Melosaurus from the Keupfer sandstone of Orenbourg in Russia was, so far as the imperfect specimen can be interpreted, quite similar to *Archægosaurus;* it has been suggested that it may be the same genus; if this is true, it would indicate a very wide range of distribution for the animal.

Trimerorachis and *Eryops* are from the Permian deposits of Texas in the United States. Only the lower division of the Permian, the Wichita division of the Texas geologists, has yielded any vertebrate fossils, but in this horizon there is a somewhat abundant fauna of amphibians, reptiles and fishes. In the neighborhood of Danville, in eastern Illinois, there have been found remains of the same amphibians that are found in the Texas deposits; the area is only a small one and is regarded as the course of an old river that has cut its bed through the underlying Carboniferous rocks. Some fragments of the same animals have been found in New Mexico. Of the genus, *Eryops*, Cope, the describer says, "this is the largest of American batrachians, the skull measuring a foot wide by eighteen inches long. It was very abundant constituting with the reptilian genus, *Dimetrodon*, the most prominent type of the Permian fauna in this country. The vertebral column is slender when compared with the size of the limbs and especially the head." Of the genus *Trimerorachis* he says, "the head of *T. insignis* is wide, flat and rounded, and its superior surface is strongly wrinkled. The lyriform mucous grooves do not extend behind the orbits. This was an abundant species during the Permian time in Texas, and probably possessed aquatic habits."

Acheloma and *Anisodexis* are forms from the Permian of Texas that are less well known than the foregoing and are perhaps synonymous with *Eryops*.

Embolerimi.—These are perhaps the most interesting of the *Layrinthodontia*; as already indicated they are distinguished by the fact that the vertebræ are made up of two rings formed by

the upward growth of the lower segment of the vertebra of the rachitomous type and the downward growth of the upper segment and its union with the two lateral segments.

Cricotus, the best known form is from the Permian deposits of Texas, the same locality as the rachitomous forms. It was rather long and crocodilian in aspect and the head was covered with the same kind of membrane plates as in the other genera but they were devoid of sculpture; the orbits were large and placed far forwards.

Diplovertebron from the Gaskohle of Bohemia is known only from fragments of the skull, limb bones and vertebræ, but the vertebræ show the same structure as *Cricotus*.

LABYRINTHODONTI (STEREOSPONDYLI).—These are the very large form that appeared at the end of the Palæozoic and reached their greatest development during the Triassic. They possessed complete biconcave vertebræ with a central foramen for the passage of the notochord. The most peculiar feature of the group, is the arrangement of the outer layer of the teeth; instead of the usual smooth layer the enamel is thrown into the most complicated folds so that a cross section of the tooth has an almost dendritic appearance. In other features than the teeth the group evinces its advanced position among the amphibians; the bones of the skull are all well ossified and the base of the skull is composed entirely of bone instead of being partly cartilaginous as in the preceding groups; there is no trace of the grooves on the upper surface of the skull to mark the position of the sensory tracts; the thoracic region is completely protected by the development of the clavicles and the interclavicle into large and strong plates that are tightly joined together; the posterior abdominal region is also protected by the expansion of the bones of the pelvis though not to the extent reached in the anterior girdle; the limb bones are all well ossified and the carpus and tarsus were entirely bony; the feet were provided with strong claws.

Trematosaurus from the Buntersandstein, near Bernberg, in Germany, was one of the smaller forms; the skull was about

24^{cm} long and rather narrow, giving the skull a rather crocodilian appearance; the edges of the maxillaries were lined with small, nearly equal sized teeth that were opposed to a similar series on the lower jaw; besides the rows of teeth on the maxillaries there were a number of larger teeth on the palatines and the vomer, covering the roof of the mouth with a strong dentition.

Metoposaurus (*Metopias*) from the Keupfer sandstone of Germany was nearly twice as large as *Trematosaurus*, the skull measuring about half a meter. The shape of the skull was much the same as in *Eryops* of the American Permian, being broad and stout, depressed from above downwards and showing a decided sculpture on the outer surface of the bones; the genus is peculiar for the very strong development of the pectoral shields, the interclavicle is a broad, diamond-shaped bone on either side of which are joined the clavicles that are also developed into broad plates, the whole covering the ventral side of the anterior portion of the body; all three of the bones exhibit a rugose outer surface.

Capitosaurus from the same locality and horizon as *Trematosaurus* was nearly as large as *Metoposaurus;* the orbits were small and elliptical; the nares large and located far forward; the extremity of the snout was broad and blunt. The same dentition is found in this as in the previous form, a series of small teeth on the edges of the upper and lower jaws and a few large tusk-like teeth on the palatines and the vomer; the surface of the skull shows a slight trace of the sensory canals and the bones are deeply pitted with grooves radiating outward to the edges of the bone.

Mastodonsaurus from the Lettenkohl, the lower division of the Keupfer, reached the largest size of any of the *Labyrinthodonti;* the skull in some specimens reaching a meter in length. The skull was rather triangular in outline; the eyes were small and the nares located far forwards; the grooves marking the course of the sensory tracts are very distinct; there was a double instead of a single row of small teeth on the edges of the upper and the lower jaws and there were two or more enlarged

palato-vomerine tusks on each side. The whole animal had a probable length of about ten feet, the head being disproportionately large.

Labyrinthodon from the same horizon as the previous forms is, according to Lydekker, a synonym of *Mastodonsaurus.* It was described by Owen from a single tooth and the name was founded on the peculiar folding of the dentine. As most all of the *Labyrinthodonti* have the same character the distinction fails; it is as well however to know the genus as the name is a common one in the text-books. (See Owens, *Odontography*, Pl. LXIII. Fig. 1, for a picture of the structure of the labyrinthodont tooth.)

Nyrania from the Permian of Bohemia and *Bothriceps* and *Micropholis* from the Permian of South Africa are less well known foreign genera. Certain imperfectly preserved remains have been collected from the rocks of the Newark system of Pennsylvania and North Carolina. *Eupelor* is the name of the small form from Pennsylvania, and *Pariosteigus* and *Dictyocephalus* from the Carolina region. Quite recently a tooth has been described from the Upper Carboniferous of Kansas, and referred to the genus *Mastodonsaurus;* if the determination is correct this indicates a rather peculiar distribution for the genus as it is unknown from the English deposits, though quite common on the continent.

Below is a summarized list of the most important forms of the *Labyrinthodontia* with their geological range and habitat so far as known.

LABYRINTHODONTIA.

Branchiosauria.

- *Branchiosaurus*, Rothliegende, Germany.
- *Melanerpeton*, *Apateon* and *Pelosaurus*, Rothliegende, Germany.
- *Protriton*, Rothliegende, France.
- *Amphibamus* and *Pelion*, Carboniferous, Ohio.

Microsauria.

- *Hylonomus* and *Hylerpeton*, Carboniferous, Nova Scotia.
- *Tuditanus*, *Osteocephalus* and *Colosteus*, Carboniferous, Ohio.
- *Hyoplesion* and *Microbrachis*, Carboniferous, Bohemia.
- *Lepterpeton* and *Keraterpeton*, Carboniferous, Ireland.

Dolichosoma and *Ophiderpeton*, Carboniferous, Ireland.
Molgophis? and *Phlegethonia?*, Carboniferous, Ohio.

Labyrinthodonta vera.

Rachitomi.

Archægosaurus, Rothliegende, Germany.
Chelydosaurus, Rothliegende, Bohemia.
Actinodon and *Euchirosaurus*, Rothliegende, France.
Trimerorachis and *Eryops*, Permian, Texas.

Embolerimi.

Cricotus, Permian, Texas.
Diplovertebron, Permian, Gaskohle, Bohemia.

Labyrinthodonti.

Trematosaurus, Buntersandstein, Germany.
Metoposaurus, Keupfer, Germany.
Capitosaurus, Buntersandstein, Germany.
Mastodonsaurus, Keupfer, Germany.
Micropholis and *Bothriceps*, Permian, South Africa.
Eupelor, *Pariosteigus*, and *Dictyocephalus*, Triassic, Pennsylvania, and North Carolina.

Besides the remains of fossil forms the rocks of the Carboniferous and Triassic times have yielded a large number of tracks, made when the animal walked across some mud flat. These tracks have received the name of *Ichnites*. Such tracks in the Carboniferous rocks are known from Kansas and Nova Scotia. Most of the tracks however occur in the Triassic rocks; the red sandstone of the Connecticut River Valley has yielded a large number. Prominent among them is the form described as *Brontozoum*. These are enormous tracks, the middle digit having a length of 12.5 inches and the whole foot 14 to 18 inches. The whole animal must have been twelve to fourteen feet long.

Anisopus from the same locality had the hind foot nearly twice as large as the front foot.

Anomœpus had five digits on the front foot and only three on the hind foot. (This form may very possibly have been reptilian).

Chierotherium or *Chierosaurus* from the Buntersandstein of Europe was about half the size of *Brontozoum*, The hind foot

was about twice the size of the front foot, and there were five digits on both. The same form is known from the Triass of Cheshire in England.

It is altogether probable that many of these tracks belong to forms already described from parts of the skeleton but until some one shall be so fortunate as to discover the skeleton and the tracks together it will be impossible to detect the synonymy. It has been suggested that the tracks referred to as *Cheirosaurus* belong either to *Capitosaurus* or to *Trematosaurus*.

The whole of the order *Labyrithodontia* dies out in the Triassic but the degree of specialization to which the members of the order attained bears ample witness to the important part they played in the fauna of the Carboniferous and the first part of the Mesozoic. Only by the demands of a most severe struggle for existence could there have arisen within the limits of a single order the necessity for the great divergence of forms that we find among the *Labyrinthodontia*. The wide distribution of the forms also bears witness to their prominence, forms being known from the East Indies, South Africa, Europe, England, and North America.

The remaining orders of the amphibians are unknown before the Cretaceous.

The *Caudata* (*Urodela*) are lizard-like, tailed animals with a naked skin and with or without persistent external gills. The skull lacks certain of the bones found in the posterior part of the skull of the *Labyrinthodontia*, as the supratemporal, supraoccipital, and the postorbital. The vertebræ are complete in a single piece. There are two suborders of the *Caudata*, the *Ichthyoidea*, in which the vertebræ are biconcave, and the *Salamandrina*, in which they are opisthocoelus or concave behind and convex in front. The common *Siren*, *Proteus*, and *Menobranchus* are living representatives of this order. Among the fossil forms perhaps the most interesting is the *Andrias* from the fresh water Miocene of Œningen. This form was described as early as 1726 by Scheuchzer, who considered the imperfect skeleton which he had as the remains of an antediluvian man, and gave

to it the name "homo diluvii testis et theoscopos." The same form was afterwards described as fish and as a lizard, until finally its true nature was made out. The form reached a length of about four feet in the largest specimens and was one of the largest of the *Caudata*. In most of its skeletal characters it was very similar to the modern *Menobranchus*.

Megalotriton is one of the *Salamandrina* from the Upper Eocene of France. It was of considerable size, judging from the vertebræ and the detached bones of the limbs. No complete skeleton has been found.

The *Anura* (*Ecaudata*) are little known from the fossil forms. They appear in the Tertiary with almost as many genera and species as at the present time, and there has been little change in the forms.

The origin of the modern forms of the amphibians is not known. Zittel says of these forms that they can in no sense be derived from the labyrinthodonts, for between these and the modern forms there exists not only a great morphological gap, but a great break in the geological record as well.

III. REPTILIA.

PAREIASAURIA.—The simplest of the *Reptilia* differ very little from the *Amphibia*. There is little in the structure of the *Pareiasauria* that might not belong to the *Labyrinthodontia* except the arrangement of the bones forming the base of the skull. Add to this that the animal did not undergo a metamorphosis from a water to a land form and the list of differences is complete. All during the Carboniferous time the conditions had been growing better and better fitted for the existence of purely terrestrial, air-breathing forms, and at the end of that time, if not, as there is reason to think, some time before, there appeared the forerunners of the great tribe of reptiles. As has been indicated, the *Microsauria* were in all probability the direct ancestors of the reptiles, but the evidence of the preserved forms is so incomplete that we do not have either what must have been the

last step of the amphibian line or the first of the reptilian. The development of reptilian forms at the beginning and throughout the Permian time was most remarkable; it seems as if the conditions had been preparing for a long time and with the dawn of the Permian disappeared the last obstruction to the growth of the reptiles which appeared at once in the greatest profusion. Not only were there great numbers of forms, but they were, even in the earliest time that we know them, already highly specialized. The group that is discussed first, the *Pareiasauria*, is nearest to the amphibia in many of its characters, while in others it is one of the most specialized of all the vertebrates. The Permian time has perhaps a larger number of highly and curiously specialized forms than any other time.

In 1840 there was discovered in the Karro formation, Permian or Permo-Triassic, of South Africa, a large number of fossil remains that were shipped to the British Museum, and there described by Professor Owen as a reptile closely related to the dinosaurs, and named by him, *Pareiasaurus bainii*. Later a nearly perfect skeleton was found and described by Professor Seeley, who redescribed the genus and species and placed it in a distinct order, the *Pareiasauria* (1863). As this animal is typical of the whole group it may be described somewhat in detail.

Pareiasaurus was one of the largest as well as one of the most amphibian-like of all the reptiles. The head was covered with large bony plates that had practically the same arrangement as in the *Labyrinthodontia;* the bones formed a complete roof, leaving only five openings in the skull, the orbits, nares, and the pineal foramen; there were traces of the sensory tracts on the surface of the skull, as in the largest of the *Labyrinthodonti;* the teeth were equal in size and distributed all around the edges of both jaws in an even series; there were small teeth arranged in rows on the palatine and the vomer bones in the roof of the mouth; the limbs were short and strong, with well-developed articular surfaces, and the feet were provided with strong claws; there were eighteen presacral vertebræ. This is of considerable

interest, as the number is the same that occurs in the turtles, and this is one of the few clues that we have as to the origin of the turtles. The vertebræ were biconcave, but were not perforated for the passage of the notochord, which was consequently divided into intervertebral segments. In the skin of the back directly over the spinal column there were developed three rows of bony ossicles, the middle row lying directly over the spinous processes and the other two lying upon each side; this development of dermal plates is regarded as the first step toward the formation of a carapace, and as an additional evidence of the connection of the *Pareiasauria* with the turtles. The thoracic girdle is stout and heavy and retains the central element, the interclavicle, which is lost in the majority of the reptiles; the pelvis was large and massive. In life the animal must have presented the appearance of a large amphibian; the legs were too short to lift the body off the ground, so the belly must have dragged as in the crocodiles; the whole body was short and squat and the tail was short; the skin was without scales and was probably thickened and folded.

Scattered bones indicate the presence of at least two other genera, *Propappus* and *Anthodus*, in the South African deposits, but not enough of the skeleton is known to warrant a description. In the American Permian deposits of Texas and Illinois there have been found a large number of forms belonging to this order; the best known are *Diadectes*, *Empedias*, *Chilonyx*, *Pantylus*, and *Pariotichus*.

Diadectes and *Empedias* are the best known of the forms; they are similar to *Pareiasaurus*, though they did not reach the size of that form; they had the same broad, flat skull with few openings; the teeth are different from the African form, in that, although they are similar in size and arranged in regular order around the edges, they are not simple in form, but are expanded laterally so that they exhibit broad grinding surfaces instead of cutting edges; they were undoubtedly herbivorous forms; the number of the presacral vertebræ is unknown, but it was probably greater than in *Pareiasaurus;* the verte-

bræ were greatly flattened in the antero-posterior direction and expanded laterally; this feature, with the short and stout limbs, led Cope to suggest that they were possibly fossorial in habit.

The three remaining forms mentioned have been placed in a separate family from the preceding, the *Pariotichidæ;* they are all smaller than *Diadectes*, never exceeding a length of two or three feet, and are further distinguished by the fact that the teeth are not equal in size in all parts of the jaw, the teeth of the middle part of the maxillary series being larger than the others. Certain of the less well known of the Texas forms show broad bony plates that extend outward from the middle of the back and cover the ribs to a large extent; they correspond to the ribs in number and position. This is a very close approximation to the condition in the turtles; in *Otocœlus* the plates are especially well developed and the lateral edges of adjacent plates meet.

The taxonomy of this group and its related forms is very imperfectly understood and there has resulted little but confusion from the numerous schemes of classification that have been proposed. When the first of the African fossils were discovered and described the name *Anomodontia* was proposed by Owen for the whole series of African forms, as he supposed that they were all closely related, but he soon recognized that this was not true and separated a group, the *Theriodontia*, to include the forms with a more carnivorous dentition. Later writers have found it necessary to depart very widely from this scheme and have founded new orders and in some cases done away with the original ones. Out of this tangle one thing seems very clear, the order *Pareiasauria* is a distinct order separate from all the rest of the Permian reptiles and is the primitive form of all the reptiles. Other forms that are closely related to this order, but whose structure is too incompletely known to make the determination of their position definite, had best here be retained in the original order *Anomodontia* as suggested by Seeley and Lydekker. The classification of the forms will then stand as follows :

Order *Pareiasauria.*
  Fam. *Pareiasauridae* (African forms).
    Diadectidae (American forms).
    Pariotichidae (American forms).
    Elginidae (European forms).[1]
Order *Anomodontia.*
  Suborder *Dicynodontia.*
    Placodontia.
    Theriodontia.

The *Dicynodontia*, including the genera *Dicynodon*, *Oudenodon*, and *Ptychosiagum* (*Ptychognathus*), are all from the same locality, South Africa, as *Pareiasaurus*, and from the same geological horizon.

Dicynodon is known only from the skull and is one of the most peculiar of the reptilian forms; the jaws were edentulous except for the presence of two large tusk-like teeth that grew out from the anterior part of the upper jaw just in the position occupied by the canine teeth in the mammals; the part of the upper jaw anterior to these teeth and the lower jaw were protected by a horny sheet similar to that present in the turtles; the posterior part of the skull was perforated by large fossae that served to lighten it considerably. This process of lightening the skull by the development of large fossae in the posterior, temporal portion, is a constant feature of all the reptiles above the *Pareiasauria* with the exception of the turtles. Many scattered bones have been found in the same deposits as the skulls of *Dicynodon* that may belong to the same genus, but there is not sufficient evidence to say definitely that this is true, and until the vertebral column and the limb bones are made out it

[1] *Elginia* is an imperfectly known form from the Elgin (Triassic) sandstones of Scotland. There are no bones preserved, but only the impression of the bones in the soft sandstone from which all the bony tissue has rotted out. The fossils were studied from casts made of the cavities left by the decayed bones. The animal was of considerable size, nearly as large as *Pareiasaurus* and the teeth were arranged in a regular series around the edges of the jaws; the appearance of the skull in life must have been most peculiar, the presence of strong rugosities on the surface of the bones of the skull show that the head was covered with large horns. *Geikia* was a related form from the same locality and horizon.

will be impossible to determine accurately their position with relation to the other reptiles.

Oudenodon was also described from the skull alone; the jaws are entirely edentulous and the appearance of the skull is strikingly testudinate. It has been suggested that this is the female of *Dicynodon*.

Ptychosiagum, or as it is more generally known, *Ptychognathus*, was very similar in many respects to the *Dicynodon*, having the same horny covering to the anterior portion of the jaws and the large canine teeth in the upper jaw; the peculiar part about the animal was the bending of the facial portion at almost a right angle to the upper surface of the skull and the upward extension of the anterior end of the lower jaw so that the mouth seemed to open on the superior face of the skull.

All of these animals must have been herbivorous; the large canine teeth were probably used to tear up the roots and aquatic plants upon which they fed. They could have been of no use as organs of offense or defense.

Placodontia.—These are rather problematical forms from the Muschelkalk (Triassic) of Germany. As in the case of the *Dicynodontia* the bones are all isolated and the various genera are known from the skulls; the few other bones that have been found in the same deposits may or may not belong with the skulls. Lydekker has called attention to the fact that all the bones that are found with the skulls are either dinosaurian or plesiosaurian; if it should turn out that the plesiosaurian bones belong with the skulls of the Placodontia it may be that that group belongs very far from the *Anomodontia* with which they are here placed, but until that is established it is perhaps best to take the evidence of the skull which points to a very decided relationship between the two groups. *Placodus* and *Cyamodus* are the two described genera.

Placodus was first described by Agassiz from a single tooth, and was regarded by him as a fish. The error was not corrected until the entire skull of the form was known. The skull was triangular in outline, very broad behind and rapidly narrowing

to a pointed rostrum in front; the orbits were large and the anterior nares very small; the posterior part of the skull shows the presence of the fossae already mentioned. The teeth are the most striking features of the skull, the anterior incisors were chisel-like and prehensile; the maxillaries were broad and flat; there were five on each side; besides the maxillary teeth there were three large palatine teeth on each side, so large that they covered nearly the whole roof of the mouth. The broad, low teeth of both this and the succeeding forms seem to indicate that the animals were accustomed to a molluscan diet.

Cyamodus was very similar to *Placodus*, but there were no prehensile incisor teeth and there were five palatine teeth, the posterior pair far exceeding the anterior ones in size.

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EDITORIAL.

It would seem that there may be need to select for technical use suitable terms to specifically designate the critical factors of the sea border phenomena described in the first article of this issue. At least three agencies coöperate in producing a structural and topographic form which has a vital geologic function, and to which specific reference may frequently need to be made without descriptive circumlocution. The same may be said of some of the contributory factors and processes involved. The functions of these are more or less masked, and even antagonized, by adventitious phenomena which need to be distinguished and excluded. (1) There is first the building of the sediments into a submarine terrace. The plane toward which this terrace is built up is identical with that toward which the land is cut down. The two processes are complementary. The degradation of the one furnishes the material for the aggradation of the other, and their final result is a base-plain continuous with a terrace plain, both alike determined by the sea level. As the former process is called baseleveling, the latter might be designated base-terracing and the result a base-terrace, but these terms are not altogether felicitous, because *base* inevitably carries the idea of something beneath rather than above, and cannot perhaps easily be made to convey the conception of an overlying plain to which aggradation approaches, and in which it finds its summit limit. A happy term for a summit plain to which aggradation is limited just as degradation is limited to a base-plain does not as yet suggest itself. (2) There is next the cutting landward of the sea edge, whereby the sea shelf is extended at the expense of the land. This is essentially a baseleveling process, and as such perhaps needs no other term than baseleveling, except as qualifiers may occasionally be required to indicate the particular mode of its action. (3) Then there

is the lifting of the sea surface, whether by filling, by the spreading of the continent in its slow movement towards isostatic equilibrium, or by changes in the sea bottom. The effects in any case are essentially the same, and are world-wide by reason of the common level maintained by the ocean in all its parts. This sea lifting combines with and modifies both the terrace building and the shore cutting, and the common result is a shelf occupied by a shallow sea. This shelf is the great theater of sedimentation and of littoral life evolution. Its peculiar configuration, by giving great breadth to the shallow water circum-continental seas upon a slight lifting of the sea level, or after the erosion and terrace building of prolonged quiescence, on the one hand, and by narrowing these shallow seas to mere fringing ribbons upon the drawing away of the sea until its shore stands against the abysmal edge of the shelf, on the other, makes it a vital factor in geological progress and gives occasion for a specific designation.

It is, however, desirable to exclude those areas that become submerged by their own individual movements and take on the similitude of submarine terraces without having any genetic or systematic relation to the sea level as such. They may stand at such depth as to give an expansion of shallow water just when the withdrawal of the sea narrows the shallow water tract on the true genetic shelf, and thus they may antagonize the evolutionary effects of the latter upon littoral life. They may, to be sure, coincide so nearly with the true shelf in position as to work concurrently with it and increase its effects, but this, from the nature of the case, will rather be the exception than the rule. Such adventitiously submerged portions of the continent must be regarded as factors that vitiate the ideal workings of the true sea-generated terrace.

Both the true sea-formed terrace and the continental border submerged by subsidence are at present embraced without distinction under the phrase "continental shelf"—a designation that fairly represents the topographic fact, but does not carry with it any specific idea of the diverse agencies involved in its

production or their opposed evolutionary functions. It does not discriminate between those features which are coöperative and world-wide, on the one hand, and those which are local and adventitious on the other.

Several terms are used tentatively in the indicated article to designate the true sea-generated terrace. Of these "circum-continental terrace," "pericoastal terrace," and "peripheral terrace" are neither brief nor especially euphonious, and only partially imply the most important relationships of the formation. The term "sea shelf" is in many respects suitable, as it indicates the configuration, in a measure, and implies, or is susceptible of implying, adaptation to the reception of sediments and to the support of littoral life — the two most vital functions which it is desired to express; but it is not clear that the phrase is sufficiently different from the already adopted "continental shelf" to make it easy to develop a technical distinction in its usage. It has, however, the merit of implying a general and not a limited phenomenon, as is somewhat obscurely suggested in "continental shelf." This general sense is peculiarly appropriate, since the terrace is as universal (at least in its initial stages) as the sea border, and is a necessary consequence of the relations of sea and land. It may, perhaps, be best to use the universal term "sea shelf" for the true genetic phases of the submarine terrace, and to leave "continental shelf" to be used in its present undifferentiated application to the submerged border of a continent without regard to its specific genesis. But this suggestion is made with the most tentative intent.

The matter is here discussed not to propose a name for acceptance, but with the quite opposite purpose of filing a caveat in behalf of a free consideration of the merits of terms and a provisional use of them until experience shall bring into clear realization precisely what needs to be named and what terms best supply the need. The basal idea of the doctrine of multiple working hypotheses is applicable to nomenclature as well as geologic theory, and its use here is suggested. The subject is believed to have sufficient importance to justify it. T. C. C.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

Hovey,[2] in notes on the Isles of Shoals, of Maine and New Hampshire, states that the general rock constituting these isles is granitic, varying in color from white to black, and that this is cut by later dikes.

Hitchcock, C. H.,[3] gives a general account of the geology of New Hampshire, including a sketch of the work and conclusions of the first and second New Hampshire state surveys and of subsequent workers in the field. Some of the modifications indicated by work done since the close of the second state survey are: (1) Archean rocks exist as oval areas in the Stamford gneiss and south of Mt. Killington, Vt., in the Hinsdale, Mass., area, the Hoosac Mountain, and elsewhere. (2) The masses of Bethlehem gneiss are batholites, with inclusions of adjacent mica-schists. (3) A study of several areas of hornblende-schist proves that they are igneous.

Daly[4] discusses the porphyritic gneiss of New Hampshire, and concludes that it is an eruptive porphyritic granite, at least in its three most important areas, of post-Devonian age.

Cushing[5] mentions pre-Cambrian rocks in Saranac township and Beekmantown, N. Y. These comprise gneisses and gabbro, upon which the Cambrian rests unconformably.

[1] Continued from page 756, Vol. IV., Jour. Geol.

The summaries of current pre-Cambrian literature which have heretofore been made by C. R. Van Hise will be continued by C. K. Leith.

[2] Geological notes on the Isles of Shoals, by H. C. Hovey (Abstract): Proc. Am. Assoc. Adv. Sci., for 44th meeting, 1895, pp. 136, 137.

[3] The geology of New Hampshire, by C. H. Hitchcock: Jour. Geol., Vol. 4, 1896, pp. 44–62.

[4] Studies on the so-called Porphyritic Gneiss of New Hampshire, by R. A. Daly: Jour. Geol., Vol. 5, 1897, pp. 684–722, 776–794.

[5] Geology of Clinton county, N. Y. (preliminary), by H. P. Cushing: Report of the State Geologist of New York for 1893, pp. 475–489.

Cushing[1] argues the existence of pre-Cambrian as well as post-Ordovician dikes in the Adirondacks and along Lake Champlain, offering the following reasons: (1) A much larger number of dikes occur in the pre-Cambrian than in the Paleozoic rocks. (2) A great proportion of the dikes are of diabase, while diabase rocks are not found outside of the pre-Cambrian areas. (3) Along the line of contact of the Potsdam with the older rocks north of the Adirondacks, the plentiful diabase dikes in the older rocks are apparently cut off by the Potsdam.

White[2] describes and maps the geology of Essex and Willsboro' townships, Essex county, N. Y. The Archean rocks of the townships comprise the following: (1) Labradorite rocks, gabbros, norites, and anorthosites, occupying the western half of the area, west of the Boquet River; (2) the metamorphic crystalline limestones and ophicalcites in the northeastern part of the area on Willsboro' Bay, and in the southeastern part of the area on the ridge of Split Rock Point; (3) gneisses and granites, chiefly on Split Rock Point. Following Adams,[3] all of these rocks are classed as Norian or Upper Laurentian.

Kemp[4] describes the geology of Essex county, N. Y. The pre-Cambrian succession in this county is as follows: (1) A gneissic series consisting of red and gray orthoclase gneisses, usually laminated, but at times rather massive. In these gneisses are the workable iron ores of the Adirondacks. (2) Apparently resting on (1), a series of crystalline limestones, ophicalcites, black hornblendic pyroxenic schists, and thinly laminated garnetiferous gneiss. Pegmatite veins are a frequent associate of these rocks. (3) A series of rocks of the gabbro family, ranging from aggregates of labradorite through

[1] On the existence of pre-Cambrian and post-Ordovician trap dikes in the Adirondacks, by H. P. CUSHING: Trans. N. Y. Acad. Sci., Vol. 15, 1896, pp. 248–252.

[2] The geology of Essex and Willsboro' townships, Essex county, N. Y., by T. G. WHITE: Trans. N. Y. Acad. Sci., Vol. 13, 1894, pp. 214–233, Pls. VI and VII.

[3] Ueber das Norian oder Ober-Laurentian von Canada, F. D. ADAMS: Neues Jahrb., B. B. VIII, p. 423.

[4] J. F. KEMP: Geology of Essex county (preliminary). Report of State Geologist of New York for 1893, pp. 433–472. See also The Geology of Moriah and Westport townships, Essex county, N. Y. Bull. N. Y. State Museum, Vol. 3, 1895, pp. 325–351. With a geological map.

varieties with increasing amounts of bisilicates to basic olivine gabbros. The gabbros vary from massive to gneissoid rocks which are difficult to discriminate from some of the gneisses of series 1. These rocks contain the titaniferous iron ores. They are intrusive in series 1 and 2. Resting unconformably upon 1, 2, and 3 is the Potsdam sandstone.

Kemp[1] describes the geology of the magnetites near Port Henry, N. Y., and especially those of Mineville in the Adirondacks of New York. The oldest rocks present in the district are quartzose gneisses and white crystalline limestones, with perhaps some more basic gneisses. The limestones appear to lie largely in the upper part of this group, but some of them are certainly below the other members. The acidic gneisses may have been granites or quartz-diorites. The gneiss and limestone group is cut by anorthosite intrusives, and both are in turn cut by gabbro intrusives. Trap dikes, usually of small width, are very common in this district. The age of these dikes is undetermined, but it seems probable that they may be of two ages, pre-Potsdam and post-Utica. Overlying unconformably all of the above described rocks is the Potsdam sandstone.

Darton[2] describes and maps the faulted region of Herkimer, Fulton, Montgomery, and Saratoga counties, New York. Laurentian rocks occupy the northern part of the area, forming the floor for a succession of sandstones, limestones, and shales, which dip to the south at a very moderate angle.

Kemp[3] describes the East River and Blackwell's Island section made by an underground tunnel at 70th street, New York City. Under the west channel is a fine grained mica-gneiss, containing pegmatite seams. Under Blackwell's Island and the adjacent waters is a gray gneiss. In the center of the east channel is a dolomite,

[1] The geology of the magnetites near Port Henry, N. Y., and especially those of Mineville, by J. F. Kemp: Trans. Am. Inst. Min. Engineers, Chicago meeting, Feb. 1897, p. 58.

[2] A preliminary description of the faulted region of Herkimer, Fulton, Montgomery, and Saratoga counties, by N. H. Darton: 14th Ann. Rept. Geol. Survey of New York, for 1894, pp. 31–56, 1896. With geological map. Published in the 48th Ann. Rept. N. Y. State Museum, 1895.

[3] The geological section of the East River at 70th Street, New York, by J. F. Kemp: Trans. N. Y. Acad. Sci., Vol. 14, 1895, pp. 273–276.

which is flanked on the east side by mica-schist, locally pegmatized. Beyond the mica-schist on the Ravenswood shore is a massive hornblende-gneiss or granite, which is thought to be intrusive.

Merrill,[1] in connection with a report on the mineral resources of New York, publishes a geological map of the entire state and a large scale geological map of the southeastern part of the state. These maps embody information available to date concerning the distribution of the pre-Cambrian rocks of New York.

Merrill,[2] in connection with a report on road materials of New York, publishes a map of the state showing distribution of pre-Cambrian rocks.

Bascom[3] describes and maps pre-Cambrian volcanic rocks of South Mountain, Pennsylvania. The volcanic rocks are both basic and acid. The acid rocks comprise quartz-porphyries, devitrified rhyolites or aporhyolites, with accompanying pyroclastics, and sericite-schists, the last being the metamorphosed forms of the quartz-porphyries and aporhyolites. The basic rocks comprise melaphyres, augite-porphyrites, slates, and pyroclastics. Lithologically the volcanic rocks resemble the Keweenawan copper-bearing rocks of Lake Superior.

There is not sufficient evidence to decide the comparative age of the basic and acid rocks, but field observations in the Monterey district indicate that the acid rocks are the older. The volcanics are overlain, with stratigraphical unconformity, but with structural conformity, by sedimentary rocks of Lower Cambrian age. Both volcanics and sedimentaries have been subjected to strong dynamic action, whereby the igneous rocks have been cleaved and sheared, and the sedimentary rocks thrust over them from the east.

Kemp[4] describes the ore deposits at Franklin Furnace and Ogdensburg, N. J., and briefly sketches the general geology of the area. The

[1] Mineral resources of New York State, by F. J. H. MERRILL: Bull. N. Y. State Museum, Vol. 3, No. 15, 1895, pp. 365–595.

[2] Bull. N. Y. State Museum, Vol. 4, No. 17, 1897, pp. 90–134. With maps.

[3] The ancient volcanic rocks of South Mountain, Pa., by FLORENCE BASCOM: Bull. U. S. Geol. Surv., No. 136, 1896, pp. 124. With geol. map.

[4] The ore deposits at Franklin Furnace and Ogdensburg, N. J., by J. F. KEMP: Trans. N. Y. Acad. Sci., Vol. 13, 1893, pp. 76–98.

ore deposits occur in white crystalline limestone, which is cut in numerous places by dikes of granite, trap, and a rock taken to be altered gabbro. The white limestone is closely involved throughout its extent with a blue limestone of Cambrian or Cambro-Silurian age.

Wolff[1] briefly describes the eruptive rocks of Sussex county, New Jersey, with reference to their economic value. These include granite, elaeolite-syenite, elaeolite-porphyry, and camptonite, and are treated under the head of Archean.

Westgate[2] describes and maps the geology of the northern part of Jenny Jump Mountain, in Warren county, N. J. The main ridge of the mountain is formed chiefly of gneisses, comprising many varieties. These are, from northwest to southeast, and also, according to the banding, from base to top (1) granitoid-biotite-hornblende-gneiss, containing narrow bands of biotite-hornblende-gneiss; (2) hornblende-pyroxene-gneiss; (3) biotite-gneiss; (4) dark biotite-hornblende-gneiss; (5) granitoid-biotite-hornblende-gneiss; and (6) dark biotite-hornblende-gneiss, and gray micaceous gneiss. Certain of the dark hornblende-gneisses have been so extensively altered as to be called epidote rocks. The gneisses are in general granitoid and massive, and there is a conspicuous absence of schistose rocks and crumpling of the banding, the banding over wide areas having uniform strike and dip.

Along the southeast side of the mountain, at the northeast end of the mountain, and in two isolated outcrops within the gneisses of the main ridge, are areas of white crystalline limestone. The limestone is in all cases closely associated, and perhaps interbanded, with the dark biotite-hornblende-gneiss and gray micaceous gneiss (Nos. 4 and 6 above), and at the northeast end of the mountain also with quartz-pyroxene rock.

Cutting both gneisses and limestone are pegmatite, diabase, and amphibolite or granular diorite.

The origin and age of the gneisses are doubtful. The presence of limestone belts closely associated, and perhaps interbanded with the

[1] Report on Archean geology, by J. E. WOLFF: Ann. Rept. Geol. Surv. New Jersey, 1896, pp. 91–94. With map.

[2] The geology of the northern part of Jenny Jump Mountain, in Warren county, N. J., by LEWIS C. WESTGATE: Geol. Surv. of New Jersey, Ann. Rept. for 1895, pp 21–61, 1896. With geol. map.

hornblendic and micaceous gneisses, and the presence of magnetic iron ore, suggest a detrital origin for at least a part of the gneisses, and consequently their reference to the Algonkian. There may be really two series of rocks: (1) A series of limestone and associated interbedded rocks, of sedimentary origin, and (2) a series of more massive granitoid gneisses, probably older, and of unknown origin. This supposition is based only on the fact that the limestones are persistently associated with the hornblendic and micaceous gneisses and quartz-pyroxene rock, and are not found associated or in contact with the light colored granitoid gneisses which constitute the main mass of the mountain. However, there is not sufficient evidence to refer a a part of the gneisses to the Algonkian, and all are therefore classed as pre-Cambrian.

The crystalline limestones are believed to be distinct from and older than the blue magnesian limestone of Cambrian age, which occurs along the northwestern side of the New Jersey Highlands, and and which outcrops in isolated areas in the valleys adjacent to Jenny Jump Mountain, for the following reasons:

1. They differ lithologically from the blue limestone in being thoroughly crystalline, and in containing large amounts of accessory metamorphic minerals, showing that they have been subjected to general metamorphic forces of which the neighboring blue limestone shows no trace.

2. They occur in intimate association with the gneisses, which are of admitted pre-Cambrian age.

3. They show no intimate association in areal distribution with the blue limestone, nor any tendency to grade into it.

4. The metamorphic changes to which the white limestones have been subjected are general in their nature, and not due to the action of eruptives by which they are cut; so that no sufficient agent is at hand to account for the supposed change from blue into white limestone. The white crystalline limestones are therefore believed to be of pre-Cambrian age.

Williams and Clark[1] describe and map the geology and physical features of Maryland. The pre-Cambrian rocks, described by Williams,

[1] Geology and physical features of Maryland, by G. H. WILLIAMS and WM. B. CLARK: Extract from World's Fair Book on Maryland, Baltimore, 1893, pp. 1–67. With map.

form the eastern or holocrystalline division of the Piedmont Plateau region of Maryland, crossing the state in a general southwest direction from the southeast corner of Pennsylvania and the north end of Delaware. These rocks are but a part of the great crystalline plateau which extends from New York to Alabama along the eastern base of the Appalachians. Towards the east the pre-Cambrian rocks of Maryland plunge under Coastal Plain deposits, and toward the west they form the floor to support the Paleozoic strata of the Appalachians, reappearing in the granitic and volcanic rocks of South Mountain of Pennsylvania. The holocrystalline rocks are divisible into six types, three of which, gabbro, peridotite or pyroxenite, and granite, are of undoubted eruptive origin, and three of which, gneiss, marble, and quartz-schist, while showing no certain evidence of clastic structure, are believed to be sedimentary. The prevailing rock is gneiss, closely associated with marbles and quartz-schists, forming an intricate complex. The complex shows evidence of great dynamic action, the rocks, having been almost completely recrystallized. The eruptive rocks are all younger than the gneisses. The gabbro is the oldest, followed by the peridotite or pyroxenite, and the youngest is the granite. The granites are as a rule medium-grained biotite-granites, but they frequently take the form of pegmatite.

Williams[1] considers the general relations of the granitic rocks in the Middle Atlantic Piedmont Plateau and maps the same. The criteria by which ancient plutonic rocks in highly metamorphosed terranes may be recognized comprise radiating dikes, inclusions of fragments, contact zones, chemical composition, and petrographical structure. On these criteria it is concluded that most of the granitic rocks of Maryland are igneous, although many of them are changed to granite-gneiss, and of certain of these gneisses it cannot be asserted whether they are of aqueous or of igneous origin. South of Laurel, in the large area from Triadelphia southward to Brookville, at Murdoch Mill west of Washington, south of Falls Church in Fairfax county, Va., and at Cabin John Bridge on the Potomac River, there are gradations between granitic rocks and diorites or gabbros. In the Maryland

[1] General relations of the granitic rocks in the Middle Atlantic Piedmont Plateau, by GEORGE H. WILLIAMS. Introduction to Origin and Relations of Central Maryland Granites, C .R. KEYES, Fifteenth Ann. Rept., U. S. Geol. Surv., 1895, pp. 659-684, Pls. XXVII–XXXV.

rocks pegmatites are abundant. Some of these are, as indicated by their association with quartz veins and by parallel banding, water segregations. The majority, however, are igneous, as is shown by all of the phenomena of intrusive rocks.

Comments.—The description and discussion of the origin of the pegmatites are of great interest. From the descriptions it is clear, although Dr. Williams does not definitely say so, that there are nearly all gradations from material which is plainly a vein quartz deposit, through others where we have quartz and feldspar with a banded arrangement, and are water segregations, to the pegmatites which have distinct igneous characteristics. This region thus affords a beautiful illustration of Van Hise's[1] conclusion that under proper conditions water and liquid rock are miscible in all proportions, and that pegmatization comprises water impregnation, true igneous injection, and all intermediate processes.

Clark[2] describes the geology and physical features of Maryland. This account is essentially the same as that published by Williams and Clark[3] in 1893, and previously reviewed. Here, however, the crystalline rocks are classed as Archean and Algonkian, both of which are included under the general term Archean. The statement is made that there is no positive evidence that there are represented in Maryland rocks of the earliest portion of Archean time (meaning Archean proper), although a part of the gneiss complex may represent it. The Algonkian period, however, is represented by many varieties of rock. The rapidity with which the crystalline rocks furnished sediments for the overlying formations points to their high elevation in Archean time.

In the western division of the Piedmont Plateau region of Maryland, Algonkian rocks are present infolded with the Paleozoic deposits of Montgomery, Frederick, and Carroll counties. They consist of a single type resembling the metamorphosed basic volcanic rocks (Catoctin schist) of the Blue Ridge district.

[1] Principles of North American pre-Cambrian geology, by C. R. VAN HISE: 16th Ann. Rept. U. S. Geol. Surv., 1894–5 pp. 686–688.

[2] The physical features of Maryland, including the physiography, geology, and mineral resources, by WM. B. CLARK: Maryland Geol. Survey, preliminary publication of Vol. 1, Pt. III, 1897, pp. 95. With map.

[3] Geology and Physical Features of Maryland, by G. H. WILLIAMS and WM. B. CLARK. Extract from World's Fair Book on Maryland; Baltimore, 1893.

Comments.—The use of the term *Archean* in two senses is objectionable. If it is used for all rocks older than the Cambrian, then another name should be applied to the basal complex. If, following the usage of the U. S. Geol. Survey, Archean is confined to the basal complex unconformably below the Algonkian, the general term for all rocks below the Cambrian should be *pre-Cambrian.*

Clark[1] describes the physical features and geology of Maryland, and gives a sketch of the development of knowledge concerning them. The description of pre-Cambrian geology is essentially the same as that given by Clark in a preliminary publication of this part of the volume,[2] and this in turn is but slightly different from an account given by Williams and Clark in 1893. Both of these articles are reviewed above. However, a few minor changes may be noted. The crystalline rocks of the Piedmont Plateau region, instead of being divided into six types as before, are divided, into seven typesdiorite being added to the list. Rocks of the Archean period are placed in the table of formations as doubtfully present.

Keyes[3] gives a detailed petrographical description of the Maryland granites. For reasons the same as given by Williams they are regarded as eruptive, and many of the gneisses are shown to be dynamically metamorphosed granites.

Darton[4] maps and describes the geology of the Fredericksburg sheet of Virginia and Maryland. He finds in the northwest and west parts that granite, gneiss, and schist occur, and in the northwest

[1] WM. B. CLARK: Outline of present knowledge of the physical features of Maryland, embracing an account of the physiography, geology, and mineral resources; Maryland Geol. Survey, Vol. 1, Pt. III, 1897, pp. 139–228; Historical Sketch, Pt. II, *ibid.*, pp. 43–138. With map.

[2] The physical features of Maryland, preliminary publication of Vol. 1, Pt. II, 1897.

Geology and physical features of Maryland, by G. H. WILLIAMS and WM. B. CLARK. Extract from World's Fair Book on Maryland; Baltimore, 1893.

[3] Origin and Relations of Central Maryland Granites, by C. R. KEYES, with an Introduction on the General Relations of the Granitic Rocks in the Middle Atlantic Piedmont Plateau, by G. H. WILLIAMS. Fifteenth Ann. Rep. U. S. Geol. Surv., 1895, pp. 685–740. Pls. XXXVI–XLVIII.

[4] Geol. Atlas of the U. S., Fredericksburg Folio, No. 13, by N. H. DARTON: U. S. Geol. Surv., Washington, 1894.

part of the area a belt of rock called the Quantico slate. This slate locally appears to grade into siliceous mica-schist or gneiss. It is about three-quarters of a mile in width, and strikes northeast and southwest. The granite, gneiss, and schist are regarded as pre-Cambrian. The slates resemble the roofing slates on James River, which carry Lower Silurian fossils.

Kimball[1] describes the magnetite belt at Cranberry, N. C., and indicates the mode of development of the magnetite. The ore belt occurs in the crystalline schists forming Cranberry Ridge. These schists are mostly basic, pyroxene and amphibole prevailing. It is suggested that they are of Algonkian age.

Keith[2] maps and describes the geology of the Knoxville quadrangle of Tennessee and North Carolina, and of the Loudon quadrangle of Tennessee. Ocoee rocks form the mountain areas. From the base upward the series comprises the Wilhite slate, the Citico conglomerate, the Pigeon slate, the Cades conglomerate, the Thunderhead conglomerate, the Hazel slate, and the Clingman conglomerate.

The Wilhite slate is bluish-gray or black argillaceous slate. In its upper portion it becomes calcareous, and contains frequent beds of limestone and limestone conglomerate. The thickness is ordinarily from 300 to 400 feet. The Citico conglomerate is entirely siliceous, and varies from fine white sandstone to coarse quartz conglomerate, with a few thin beds of sandy shale. The Pigeon slate is mainly an argillaceous slate of great uniformity, occasionally banded by thin seams of coarser siliceous material. The thickness varies from 1300 to 1700 feet.

The Cades conglomerate, the Thunderhead conglomerate, the Hazel slate, and the Clingman conglomerate, are not described for the Loudon quadrangle.

For the Knoxville quadrangle the Cades conglomerate consists of thick beds of slate, sandstone, graywacke, and conglomerate. The

[1] The magnetite belt of Cranberry, N. C., by J. P. KIMBALL: Am. Geol., Vol. 20, 1897, pp. 299–312.

[2] Geol. Atlas of the U. S., Knoxville folio, No. 16, by ARTHUR KEITH: U. S., Geol. Surv., Washington, 1895.

Ibid., London folio, No. 25, 1896.

apparent thickness is 2400 feet, and this may be an overestimate, because the formation may be repeated by folding. The Thunderhead conglomerate consists of a series of conglomerates, graywackes, and sandstones, with many small beds of slate. The thickness is believed to be about 3000 feet. The Hazel slate is chiefly a black slate, but it contains many thin beds of sandstone and conglomerate in small quantity. The exact thickness cannot be ascertained, but it is believed to be about 700 feet. The Clingman conglomerate is the same in composition as the Thunderhead conglomerate, except that in the Clingman conglomerate there is smaller development of slate beds.

The age of the Ocoee rocks is undetermined, and they are therefore mapped as of unknown age.

Hayes[1] maps and describes the geology of the Cleveland quadrangle of Tennessee. Ocoee rocks occupy the southeastern part of the quadrangle, forming Big Frog Mountain and the plateau along its western base. No fossils have yet been found in these rocks, and they are separated by a great fault from rocks of known age, so that their position in the stratigraphic column cannot be fixed with certainty, but since they bear the marks of extreme age, they are considered as probably Algonkian. The Ocoee series comprises in this area the following formations, from the base upward : the Wilhite slate, the Citico conglomerate, the Pigeon slate, and the Thunderhead conglomerate and slate. Their correlation with formations bearing the same names in the Knoxville quadrangle to the northeast, described by Keith, is only approximate. The Wilhite slate consist in the main of dark blue or black slate. The Citico conglomerate varies from a coarse, massive conglomerate to fine grained sandstone or quartzite in sandy shale. The thickness varies from 500 to 1150 or more feet. The Pigeon slate resembles the Wilhite slate, the chief difference being a frequently observed banding and an abundance of interbedded gray schistose sandstones and graywackes, and occasional conglomerates. The Thunderhead conglomerate and slate can be separated into three divisions. The lowest of these, from 800 to 1000 feet thick, is a massively bedded conglomerate, made up largely of blue quartz and feldspar pebbles. The middle division consists of interbedded black slate and schistose conglomerate or sandstone, the slate apparently

[1] Geol. Atlas of the U. S., Cleveland folio, No. 20, by C. W. HAYES : U. S. Geol. Surv., Washington, 1895.

predominating. The upper division is also composed of conglomerate and slate, but the slate is comparatively unimportant.

King[1] describes the geology of the "Crystalline Belt" of Georgia, in connection with the occurrence of corundum. The Crystalline Belt occupies an area of 12,430 square miles, crossing the northern part of Georgia from the northeast to the southwest, and lying between Paleozoic strata in the northwest corner of the state, and Mesozoic and Cenozoic strata in the southern half of the state.

The rocks of the Crystalline Belt are divisable into two petrographical classes. The first consists of a series of mica-schists, slates, shales, conglomerate, and marble, which, though more or less crystalline, show evidence of clastic character. This class is called the *semicrystalline* series. The semicrystalline rocks are confined to an area bordering the Paleozoic to the northwest. The second class comprises eight types of rock. Three of them, limestone, quartzite, and slate, are undoubtedly clastic; three of them, granite, gneiss, and mica-schist, are completely crystalline and show no trace of clastic character; and two, peridotite, and diorite, are presumably of eruptive origin. Gneiss and mica-schist are the prevailing rocks. This second class is termed the *holocrystalline* series.

The rocks of the Crystalline Belt are separated from the Paleozoics on the northwest by a strong unconformity. Between the semicrystalline and holocrystalline rocks there is apparent transition.

Throughout the Crystalline Belt there is a uniform dip to the southeast, pointing toward a moving force from the southeast, but in the holo-crystalline area the dip is much steeper than in the semicrystalline area. Disturbances and alterations are more extensive in the holocrystalline rocks than in the semicrystalline rocks. Corundum is present only in the holocrystalline rocks.

From these facts it is believed that the holocrystalline area is older than the semicrystalline area, and formed the continent against which washed the waters of the sea which deposited the rocks of the semicrystalline series. While a portion of the holocrystalline series may be Archean, because of the presence in it of undoubted clastics the series is referred to the Algonkian. The same reference is made for the semicrystalline rocks.

[1] Corundum deposits of Georgia, Chap. iv, Geology of the Crystalline Belt, by Francis P. King: Bull. Geol. Surv. of Georgia, No. 2, 1894, pp. 58–72.

The history, varieties, and characters of corundum, and its mode of occurrence in the holocrystalline rocks, are fully described.

Smith[1] gives a general account of the character, distribution, and structure of the crystalline rocks of Alabama. The rocks are altered sedimentary and igneous rocks. The altered sedimentary rocks, called the Talledega or Ocoee series, is referred to the Algonkian, and the altered igneous rocks are referred to the Archean.

The Talledega series is found in the northeastern part of the state, in four or five roughly parallel belts, running northeast and southwest, the strata in general dipping to the southeast. The series comprises, in order of abundance, clay-slates or argillites, in places impregnated with graphite, quartzites and quartzite conglomerates, and crystalline limestones or dolomites. The slates, quartzites, and conglomerates resemble very strongly certain strata of undoubted Cambrian age, and it is probable that some of the strata included with the Talledega are altered Cambrian rocks. As yet, however, no fossils have been discovered in them.

The altered igneous rocks occur in three main belts roughly parallel with the sedimentary belts in the northeastern part of the state. In order of abundance they are gneisses and mica-schists, cut by dikes of granite, diorite, and various hornblendic, pyroxenic, and chrysolitic rocks.

Gold ores are associated with both the sedimentary and igneous series. Their mode of occurrence is briefly sketched.

Brooks,[2] in petrographical notes on some metamorphic rocks from Alabama, makes general statements concerning the geology of the metamorphic rocks of Alabama and Georgia. The metamorphic rocks of Alabama and Georgia may be differentiated into two series. The older, or crystalline series, includes crystalline schists and gneisses, whose origin is doubtful, together with large masses of gneissoid granite. The younger, or clastic series, is typically made up of phyllites, sericite-schists, chlorite-schists, conglomerates, quartzites, crystal-

[1] A general account of the character, distribution, and structure of the crystalline rocks of Alabama, and of the mode of occurrence of the gold ores, by E. A. SMITH: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 108–130.

[2] Preliminary petrographic notes on some metamorphic rocks from Eastern Alabama, by A. H. BROOKS: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 177–197,

line sandstones, and in a portion of the region limestones and marbles. The rocks of both series are closely associated with rocks of undoubted igneous origin.

Clements[1] gives notes on the microscopical character of certain rocks from the crystalline area of northeastern Alabama. The rocks include sedimentary and igneous rocks, and others whose origin is unknown. The sedimentary rocks are comparatively unimportant. Disregarding the sedimentary rocks, the rocks as a whole have the characters of Archean rocks.

Hawes[2] gives notes on the microscopical characters of the Alabama crystalline or metamorphic rocks.

Darton,[3] in connection with a discussion of artesian well prospects in the Atlantic Coastal Plain region, briefly describes the occurrence of the crystalline rocks. The crystalline rocks, predominantly granite and gneiss, outcrop along a line which passes from New York City through Philadelphia, Baltimore, Richmond, Weldon, and Columbia, to Augusta, Ga., and thence through Georgia and Alabama. Westward they extend up the gentle slope of the Piedmont Plateau to the base of the Appalachians. To the east they dip below unconsolidated sedimentaries, and along the ocean shore, from New Jersey south, they are 2000 feet below the surface.

GENERAL COMMENTS.

As yet the broader structural problems of the crystalline and semi-crystalline rocks of the Appalachian region and the Piedmont Plateau are far from completely solved. It is certain that some of the semi-crystalline rocks which in former years have been called Algonkian or Archean are Paleozoic. It seems equally certain that in the Appalachian and Piedmont Plateau region are greatly metamorphosed sedi-

[1] Notes on the microscopical character of certain rocks from Northeast Alabama, by J. MORGAN CLEMENTS: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 133–176.

[2] Notes on the microscopic characters of the Alabama crystalline or metamorphic rocks, by G. W. HAWES: Bull. Geol. Surv. of Alabama, No. 5, 1896, pp. 131–132.

[3] Artesian well prospects in the Atlantic Coastal Plain region, by N. H. DARTON: Bull. U. S. Geol. Surv., No. 138, 1896, pp. 18–19.

mentary rocks, many of them being completely crystalline schists and gneisses, which are of pre-Paleozoic age. Further, in this region is a great series of sedimentary rocks known as the Ocoee series, the position of which is not determined, but which may include both Paleozoic and pre-Paleozoic rocks. Apparently all of the series of sedimentary rocks thus far mentioned rest unconformably upon a still older granite-gneiss-schist complex. It therefore appears clear that there are at least three series of rocks represented in the Appalachian region and the Piedmont Plateau, and there may be more.

Until the great structural problems of the Appalachian and Piedmont Plateau region are settled, the only safe course is to call pre-Paleozoic the rocks which are certainly below the Paleozoic, leaving open the question of their further classification as Archean or Algonkian. In the case of the Ocoee, at the present time, the series cannot be placed even as closely as pre-Paleozoic. In work in Maryland, North Carolina, Tennessee, Alabama, and Georgia, as shown by the above summaries, this plan in some cases has not been followed, but rocks supposed to be of pre-Paleozoic age have been somewhat arbitrarily assigned to the Archean or Algonkian. The use of these names, without definite knowledge of the structural features as a basis for the reference, is a hindrance rather than a help to further classificatory work. When the age of a series in the region is more definitely determined, the rocks can be placed as Algonkian or Archean without contradicting previous statements. C. K. Leith.

Reviews.

United States Geologic Atlas, Folio 42, Bidwell Bar, California. 1898.

This folio consists of six pages of text, signed by H. W. Turner, geologist, a topographic map of the district, a map showing the areal geology, and a map showing the economic features, with one page of special illustrations. The quadrangle represented in this folio lies between the parallels 39° 30′ and 40° north latitude and 121° 30′ and 121° west longitude. It comprises a portion of the northern Sierra Nevada and lies chiefly in Plumas and Butte counties. Except a small area in the southwest corner, the quadrangle is drained entirely by the Feather River. As in the other Gold Belt folios, the formations are divided into two main groups: The Bed Rock series, and the Superjacent series.

Bed Rock series.— In this quadrangle the Bed Rock series is comprised very largly of old igneous rocks with minor amounts of Palæozic sediments. In the northeast corner a single belt of slates, known to be of Juratrias age, is noted. The age of the Palæozoic rocks is known to be in part Carboniferous. In the Diadem lode there occur silicified tests of foraminifera, *Loftusia columbiana* Dawson, this being the first time this fossil has been found in California. Its age is Carboniferous. Other Carboniferous fossils were found at other points in the Calaveras formation. The igneous rocks belonging to the Bed Rock series may be grouped under three main headings:

1. Amphibolite and amphibolite schists, diorite and porphyrite. In all of the rocks of this series, excepting some of the porphyrite, there is a large amount of green aluminous amphibole. The main mass of the rocks of this group are metamorphic lavas and tuffs.

2. Magnesian rocks, comprising serpentine, talc, chlorite and colorless amphibole rocks, all of which appear to be merely different alteration products of rocks of the peridotite and pyroxenite family. The serpentine has resulted from the alteration of facies of the magma rich in olivine and rhombic pyroxene, and the talc, chlorite and colorless amphibole schists from other facies rich in aluminous pyroxene. The

colorless amphibole comprises probably both edenite and gedrite. The magnesian rocks above described are cut by soda-feldspar dikes, which appear to have a genetic connection with the peridotite-pyroxenite magma.

3. Granular intrusive rocks, mostly acid in character, including granite, granodiorite, quartz-diorite and gabbro. All of the granitic rocks are cut by dikes of aplite, which is regarded as the residual acid material of the magma squeezed up into cracks after the consolidation of the granitic rock; and by dikes of a fine grained diorite, which usually contains idiomorphic needles of brown amphibole. The occurrence of these fine grained diorites or diorite-porphyries in small dikes at widely separated intervals in the Sierra Nevada, suggests that they are the differentiation product of some other magma. These dike rocks are very similar in mineral and chemical composition at widely separated localities, and appear to be among the latest of the pre-Cretaceous intrusives, inasmuch as the dikes cut nearly all the pre-Cretaceous rocks. It does not seem possible to ascribe the origin of these dikes to a batholithic magma, underlying the range, inasmuch as the rock occurs almost nowhere in masses sufficiently large to be represented as areas on the geological maps. A genetic connection with the great granodiorite batholith underlying the Sierra Nevada, is suggested by the field relations of this diorite-porphyry.

Superjacent series.— The rocks of the Superjacent series in the Bidwell Bar quadrangle consist almost entirely of gravels and Tertiary lavas, and tuffs. During the Neocene period the Bidwell Bar quadrangle was a country of low relief, as were other portions of the Gold Belt. The Auriferous river gravels formation represents deposits made by the rivers of the Neocene period. These are very largely covered at the present time by lavas. While volcanic rocks are very abundant, there appears to have been few volcanoes in the district. The lavas come chiefly from vents located in the Downieville quadrangle, which lies just east. This is not true, however, of the lavas of the plateau west of the north fork of the Feather. These originated in the Lassen Peak volcanic area.

West of Franklin Hill is the base of a former volcano. The Superjacent volcanic rocks are grouped under the following heads:

Basalt:

Older basalt, with litle olivine.

Later basalt, dark colored and rich in olivine.

Andesite :

Hornblende-andesite, tuff or breccia.

Fine grained hypersthene-andesite.

South of Campbell Peak in the canyon of Fall River, is a dike-like mass of fragmental andesite. This is exposed in the bed of the river, and it extends vertically up the sides of the canyon. In the dike material are embedded the fragments of fossil wood (sequoia) It is clear that this dike represents a fissure opened by an earthquake (?) and filled in by the fragmental andesite from above.

Meadow Valley in the northeast corner represents a depressed area, the result of faulting in early Pleistocene time. During a portion of the Pleistocene, this valley was occupied by a lake.

On the northeast slope of Spanish Peak ridge are fine moraines, and evidences of glacial action were found also at many other points. The lowest elevation which sheltered on its north slope a glacier during the glacial period, is the ridge southwest of Buck's Valley. At one point what appeared to be a morainal pond had been formed by a small glacier. The top of the ridge south of this pond has an elevation of only 5800 feet. As a general rule it may be said that in the Sierra Nevada, all those slopes which now shelter snow banks during the entire season, nourished glaciers during the glacial period.

Structure.— A figure is introduced into the text, showing the general parallelism of the schistosity to the granitic masses, which represent intrusions into the schistose rocks. It will be noted, however, that narrow tongues of the granitic rocks at some points cut directly across the schistosity, and it appears probable that the schistosity in the main was developed at a period antecedent to the granitic intrusions and that the parallelism of the lines of schistosity to the contact of the entering granite, is due to these masses being forced aside by the intrusive rock, the separation of the schistose masses taking place most readily parallel to the schistosity. There is evidence of faulting on an extensive scale in the northeast portion of the quadrangle to the east of Spanish Peak, and faulting was noted at the head of Dogwood Creek. A photograph of this fault scarp is reproduced on the illustrations sheet.

Economic geology.— The economic features of the district include a description of the gold vein deposits, and of manganese, iron, chromite and lime and marble deposits. While quartz is the ordinary vein material of the gold deposits, one instance of an auriferous barite vein is noted.

North Carolina Geological Survey. J. A. HOLMES, State Geologist, Bull. 13; Clay Deposits and Clay Industry in North Carolina, by HEINRICH REIS.

There are few things more noticeable and at the same time more gratifying in the recent work of the state geological surveys than the increased attention paid to the economic and industrial portion of the work. So long as it remains necessary to justify the existence of surveys to appropriation committees, it will remain pleasant to point to practical work and direct economic returns in neighboring states. It has been abundantly shown that legislators do not usually object to paying for a reasonable amount of purely scientific investigation, provided only that the practical work waiting to be done be not slighted. It is equally well demonstrated that it is only by conducting work along lines of both pure and applied science that state surveys attain their highest usefulness. They do better work and gain more quickly and hold more securely the confidence of those who pay for this work. Neglect of these truisms has led to the premature cutting off of more than one survey. It is pleasant, accordingly, to note that the reports coming from North Carolina are not only scientific in their accuracy, but practical in their scope. Such a paper as the one under review, by stimulating the development, and, in a sense, advertising the clay resources of the state, must inevitably be followed by direct material benefits. The care taken by the author to suggest changes and improvements in present treatment as well as to note lines of expansion, in view of his wide experience with clays, are exceedingly valuable.

The paper opens with a brief statement of the origin of clays, and a classification of those developed in North Carolina. This is followed by a clear, though condensed, discussion of the chemical and physical properties of clays and of the geography and geology of the North Carolina deposits. The kaolin or china clays, pottery clays, fire clays, pipe clays, and brick clays are then discussed briefly with reference to distribution, character and proper treatment. A large number of analyses and tests have been made, and are not only inserted, but are interpreted. To persons outside the state the chapter devoted to the kaolins will naturally attract the most attention, since it is kaolin from North Carolina which figures so largely in the pottery industry of the whole country. Judging from certain facts brought out in the report the time may come when the kaolin will be extensively used in its

home state. There will, however, be many matters to consider before the attempt is made. The present, being a preliminary report, leaves this as well as many interesting problems of cost, production, markets, and treatment almost untouched. We would like, for example, to know more about the fuel and labor costs, the type of dry houses and speed of drying found best adapted to the various clays, methods of burning, length of water-soaking, and many other things. These will, of course, be discussed in the final report, which will be eagerly anticipated by all interested in the clay industry.

Among the most valuable things in the present paper are the rational analyses and the large number of physical tests. The latter include the determination of the percentage of water necessary to give a workable paste, the approximate plasticity, the speed of slaking, texture, percentage of air and fire shrinkage, average and maximum tensile strength per square inch, the point of vitrification, vitrification and viscosity temperatures, total fluxes, color when burned, and specific gravity. There is nothing new or especially accurate with regard to the plasticity determinations, such general expressions as "lean," "fair," "good," etc., being used. It is not stated how many tests were used in getting the average tensile strength, nor is the range of variation given. In view of the method adopted, a minor variation from the standard cement test, the omission is important. For example, the pottery clay (No. 50) from Blackburn in Catawba county, gave an average tensile strength of 148 pounds, with a maximum of 200 pounds per square inch. Assuming that the minimum varied as much from the average as the maximum, and we have as the result a clay with tensile strength varying from 96 to 200 pounds, over 100 per cent. While some of the figures are closer, this is not exceptional except in the high strength. Other variations are 84 average to 120 maximum, 60 to 81, 14 to 16, 15 to 18, etc. In short, the results, judging from the imperfect data presented, show as wide or wider variation than is common in cements, and there is the same need here for an improved and more accurate test that cement users recognize. It would be interesting to know more also as to the methods adopted in making some of the tests. For example, does the percentage of water necessary to give a workable paste have reference to clays dried to a uniform state or taken from the bank? The difference might be considerable. Was the shrinkage measured in bulk on market products or along single directions on tests bricklets? Without this data the

results are somewhat less valuable for general comparison, though still of great importance. As a whole the report is to be highly commended. It is concise and fresh. It tells not only about North Carolina clays, but incidentally it gives the point of view of the modern student of clays. While no new methods are developed, there are no modern methods of value which have been overlooked. In addition to its other excellent features the paper is well printed and sufficiently illustrated.

H. F. BAIN.

Lehrbuch der praktischen Geologie. Arbeits- und Untersuchungsmethoden auf dem Gebiete der Geologie, Mineralogie, und Paleontologie. Von DR. KONRAD KEILHACK, Kgl. preuss. Landsgeologen in Berlin. 639 pp. Stuttgart, 1896.

The title of this book fairly indicates its scope. It is essentially an exposition of the results to be sought in the field, and in the laboratory study of the materials gathered in the field, and of the methods by which these results are attained. It is the only book with which we are familiar which essays to deal with so comprehensive a subject. Geikie's *Outlines of Field Geology* covers in a briefer way some part of the ground of the present volume. Richtofen's *Führer für Forschungsreisende* gives many suggestions along the same lines. Nevertheless the present volume is so much more comprehensive than anything else which has been written on the subject that it may fairly be said to be without a rival.

Formidable as was the task which the author set for himself in the preparation of this work, it must be said to have been well done. Probably no two geologists would give instructions for the same work in the same way, and no one could be expected to make a treatise on so broad a subject equally satisfactory in all its parts; yet with all the exceptions which might be taken to the order or method of treatment, and with all the shortcomings which specialists in this department or that might point out (and they are neither numerous nor serious), the book might be read with profit by every geologist in the early stages of his work, and many parts of it by men who are no longer novices. The volume is naturally more satisfactory in those departments of geology where study has been longest prosecuted, and where methods and principles have become most firmly established; for example, the

sedimentary fossiliferous rocks. It is less satisfactory (chiefly because of its brevity) in its discussion of the methods applicable to metamorphic rocks, and to formations which are not indurated, and which contain no fossils, such as the drift and the late Tertiary and Pleistocene formations outside the drift-covered areas. Adequate directions for detailed work in these departments of geology would perhaps have carried the author beyond the limits of a volume intended primarily for those who are beginning practical work in geology, and for the intelligent reader who seeks to understand the nature of the work which geologists have to do and the results to which their work leads.

The criticism might be made that at some points the book goes into too great detail. Here and there specifications are given which any student who has had even fairly adequate instruction does not need. If the author intended to make the book so complete that it might be of service even to those who have not had adequate instruction, these details are in place; but for young geologists who have had the teaching which most young men who enter the profession in our country have had, some of the simpler matters might have been omitted.

The volume is so helpful in many ways that teachers of geology would do well to encourage its study by students who expect to make geology a special study. R. D. S.

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THE

JOURNAL OF GEOLOGY

SEPTEMBER–OCTOBER, 1898

GEOLOGY OF A PORTION OF THE SOUTHERN COAST RANGES.[1]

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INTRODUCTION.

It is the intention to present in the following paper a résumé of the most important results obtained during a detailed study of a portion of the southern Coast Ranges of California.

The area embraces about 570 square miles in the western part of San Luis Obispo county with the town of the same name nearly in the center. It has a length from north to south of thirty-five miles and an extreme width from east to west of

[1] Published by permission of the director of the United States Geological Survey.

twenty-nine miles. The seacoast traverses it diagonally forming the southwest boundary. The region is one of complex structural features and has represented within it nearly all the sedimentary formations characteristic of the Coast Ranges as well as a great variety of igneous rocks. As far as the writer has yet studied the Coast Ranges no other region of equal area has been found to contain so much of geologic interest.

More than six months of the past year has been devoted to field work[1] in this region besides several reconnoissances in former years. It is expected that a part of the results will appear in the form of a folio of the United States Geological Survey, and a complete report later in one of the Annuals.

TOPOGRAPHIC FEATURES.

The main topographic features have a northwesterly and southeasterly direction. The Santa Lucia is the highest and most important mountain range, extending parallel with the coast across the center of the area surveyed. On the south forming the high ridge terminating on the ocean in Point Buchon is the San Luis range. Crossing the northeast corner of the area is the northern extension of the San Jose range. All three ranges are traversed by narrow canyons which open upon broad and almost level or undulating valleys which extend in a northwest and southeast direction between these three important mountain blocks. The area is thus divided into two portions with sharply contrasted cycles of development, that is, recent mountain ranges with steep slopes and traversed by narrow canyons, and broad valleys in an advanced stage of base-leveling.

The Santa Lucia range forms the divide between those streams which flow directly into the Pacific Ocean and those which drain into the Salinas River. The valley of the upper portion of this river crosses the region surveyed between the

[1] The writer was aided in the field by Mr. F. E. Harvey, a senior student in Stanford University, and Mr. Robert Moran of San Luis Obispo, both enthusiastic students.

Santa Lucia and San Jose ranges. South of the Santa Lucia, between it and the San Luis range, are the broad and fertile San Luis and Los Osos valleys opening northwestward to Morro Bay. A series of sharp peaks extends from a point a little south of the town of San Luis Obispo northwest to Morro Rock separating these valleys from the foothills of the Santa Lucia range.

The Santa Lucia range as far as its recent movements are concerned forms a geological unit, and viewed from the south it presents a bold and comparatively regular front and even sky line. The highest portion has an elevation of nearly 3000 feet, and the summit a width of two to four miles. The topography of this range while presenting certain common features yet varies greatly in different portions, owing to the marked variation in resistency offered to erosion by the different geological formations. The Monteveys hales, which are mostly confined to that portion east of Cuesta Pass, are cut by deep V-shaped canyons while northwest of this pass the soft Knoxville shales, extending longitudinally through the centre of the range, exhibit a succession of open valleys.

The granite mountains (San Jose range) in the northeastern corner of the area surveyed reach an elevation of nearly 2000 feet, but do not seem so high because of the elevated valleys about them. They are cut by narrow canyons, but do not rise as abruptly from the adjoining valleys as the Santa Lucia range. This elevation of land is a magnificent example of an ancient base leveled mountain range. Viewed from most any point along the foothills of the Santa Lucia range the numerous furrowed ridges fall into an even sky line many miles long.

The San Luis range attains an elevation of a little over 1800 feet. It consists of a series of sharp ridges traversed by deep narrow canyons. To the east it lessens in height and finally blends with the Santa Lucia range.

The line of buttes extending from the vicinity of San Luis Obispo northwestward and terminating in Morro Rock constitutes the most remarkable scenic feature in the landscape. The buttes

rise from 400 to 1500 feet from open valleys which are but little elevated above tide level, and terminate in Morro Rock which rises out of the ocean to a height of nearly 600 feet. These are undoubtedly peaks of erosion, the hard crystalline rock of which they are composed weathering away much more slowly than the soft strata of the Golden Gate series in which they were intruded.

The extensive valleys south of the Santa Lucia range are underlaid by the oldest sedimentary rocks (Golden Gate series) of the sheet and are, in their general features, of great antiquity compared with the abrupt mountain ranges on either hand. The valley block has acted practically as a unit since the period of disturbance giving rise to the Santa Lucia and Buchon ranges.

The principal hydrographic basin is that of the Salinas. This stream flowing across the northeast corner of the area pursues a comparatively regular course until it empties into Monterey Bay. The remarkable thing, however, about the river is, that instead of flowing in the lowest depression between the Santa Lucia range and the granite mountains, it has cut a channel for a number of miles through the granite flowing in a canyon 500 to 700 feet deep.[1] Its meandering course brings it in places to the edge of the granite, where it receives tributary streams from the Santa Lucia. These transverse streams have so eroded their separating divides in the soft sandstones between the two ranges that they form an almost continuous valley which is strictly a continuation of the valley of the Salinas farther down. This is clearly a case of superimposed drainage, for when the course of the Salinas and its tributaries was originally outlined the present valley region must have been higher than the granite ridge.

A similar superimposed drainage is to be observed in the case of the streams which flow southwesterly from the Santa Lucia range. These traverse the broad open stretches of the San Luis valley, which in its lower portion is not over 200 feet

[1] Jour. Geol., Vol. V, p. 576.

above the sea, and separated from Los Osos valley by a divide not 50 feet high, and then pass directly into the San Luis range, cutting across it in narrow canyons at right angles to its course for a distance of over three miles. The most westerly of these streams, the San Luis Creek, has cut through where the range is 1000 feet high ; and the other, Pismo Creek, traverses it where it is but little lower. The watershed between these streams has almost disappeared, and but little change in the topography would cause the whole drainage to pass westward along the northern slope of the San Luis range to Morro Bay. When the courses of these streams were originally outlined the San Luis range probably did not exist, and the general slope of the country was southwesterly. With the beginning of the upward movement along the axis of the range erosion continued to be rapid enough so that the original drainage was maintained.

SEDIMENTARY TERRANES.

An almost continuous series of sediments from the Middle Mesozoic down to the present is represented in different portions of the central and southern Coast Ranges, but owing to the oft repeated mountain-making disturbances the series is not complete at any one spot. Except for the absence of the Horsetown beds, the Eocene, and possibly the marine Pliocene, the series is practically complete in the region under discussion.

In the northern portion of the Santa Lucia range and other portions of the Coast Ranges there is still an older series of sedimentary rocks which are of unknown age, but were involved in the granite magma at the time of its formation and now appear as marbles, schists, etc. All that is known about these rocks is that they are older than the granite, and that the granite itself is much older than the Golden Gate series (Jurassic) which rests upon it with a basal conglomerate. None of these metamorphic rocks appear associated with the granite north of the upper Salinas River, although farther northwest along the same crystalline axis they are extensively developed.

JURASSIC PERIOD.

Golden Gate series. — This series forms the base of the unaltered sedimentary rocks in the central and southern Coast Ranges. The exact position of these rocks in the geologic scale remained a puzzle to geologists for many years, partly because of the scarcity of fossils, and partly because of the obscure stratigraphic relations.

In former papers[1] the writer has advanced considerations for the belief in the pre-Cretaceous age of this series of rocks, and that it underlies the Knoxville unconformably. In later papers[2] the series was named and more definite proofs given of its relation to the Knoxville. During the recent detailed study of the region about San Luis Obispo the question was conclusively settled in favor of the position maintained by the writer. Two lines of evidence aided in the determination. The first concerns the relation of the series to the Knoxville. Both of these groups of rocks are extensively developed in the region in question, each with its characteristic features. The Golden Gate series is most largely exposed along the southern slope of the Santa Lucia range, in the large valleys at its base, and on the northern slope of the San Luis range. A narrow strip also occurs on the northern side of the Santa Lucia range, exposed through faulting. The Knoxville beds begin as scattered outcrops on the southern slope of the Santa Lucia range east of the town of San Luis Obispo and extending northwest through the depression in the range known as Cuesta Pass, expand to form many square miles of mountainous country through the heart of the range. At numerous points on the northern slope of the range, from the Eagle Ranch to the head of Morro Creek, were found patches of the basal Knoxville conglomerate, either resting upon the upturned Golden Gate series, or upturned itself and faulted down into the latter series. Specimens of Aucella were found in strata of sandstone and fine conglomerate within four feet of

[1] Am. Geol., Vol. IX, p. 153; Am. Geol., Vol. XI, p. 70; Bull. Geol. Soc. Am., Vol. VI, p. 71.

[2] Jour. Geol., Vol. III, p. 415; Am. Geol., Vol. XVIII, p. 350.

the base of the beds. Near the road, two miles northeast of San Louis Obispo, the base of the Knoxville beds is exposed on a little hill. It consists of conglomerate, perhaps thirty feet thick, and dips easterly at a low angle. Exposed on either side of the hill and passing through under the conglomerate is one of the pre-Cretaceous basic intrusives similar to others near by in the Golden Gate series. This must have been the old sea bottom on which the conglomerate was deposited. In Reservoir Canyon, a little more than a mile southeast of this locality, is a hill about one-half mile in diameter formed of Knoxville shales and one thin layer of conglomerate. The shales are but little inclined and are underlaid and surrounded on all sides by the upturned and nearly vertical sandstones and associated intrusives of the Golden Gate series. Perfectly preserved specimens of *Aucella* were obtained from a concretionary nodule at the very base of the Knoxville on the south side of the hill.

The second line of evidence, that of palæontology, leads to the conclusion that the series is not older than the Jurassic, the radiolaria as well as the molluscan remains both agreeing upon this point. All the specimens of the latter so far obtained from the series are probably new species and appear to be indeterminate as far as the question of Jurassic or Cretaceous age is concerned. Only one locality of mulluscan fossils was discovered and that is located on the coast, six miles north of Port Harford. A small species of a pecten-like form occurs in great abundance here through a thickness of about eighty feet of black slate which stands vertical and is inclosed between dikes of diabase.

The strata of the Golden Gate series consist of sandstone which forms fully four-fifths of the whole, numerous lenticular beds of radiolarian jasper, shale, and a little conglomerate. The whole has been upturned, folded, and faulted in a very complex manner and intruded at various periods by dikes of igneous rocks in great variety and abundance. The different members of this series have the same character as in other portions of the Coast Ranges where they have been described.[1]

[1] Bull. Geol. Soc. of Am., Vol. VI, p. 82; U. S. Geol. Sur., XVth Annual Report, p. 415.

The sandstone is characteristically thick bedded and in general shows little if any metamorphism, except in the vicinity of eruptive masses. It disintegrates readily, forming a rather heavy soil. It is almost everywhere, however, seamed and fissured, while the softer, shaly strata are often crushed and distorted. The five-mile section along the coast, north of Port Harford, exhibits the relative proportion of sandstone in the series. Along this stretch the strata stand vertical and with the exception of thin layers of shale and several lenticular strata of jasper consists entirely of sandstone. The apparent thickness of this section is fully 10,000 feet, but whether this represents the total thickness of the Golden Gate series is not certain.

The outcrops of jasper are very abundant over the whole of the region occupied by the Golden Gate series, and as they weather away much more slowly than the sandstones form the most prominent of the smaller topographic features, rising often as jagged or rounded knobs above the rolling contour of the hills. There are at least half a dozen important horizons, which, though apparently not confined to any one portion of the series yet are mostly aggregated toward what seems to be the basal portion. The strata of jasper are of very irregular dimensions swelling and pinching and often appearing as isolated lenses, but rarely exceeding 100 feet in thickness. The basic intrusives so numerous in the Golden Gate series occur mostly in that portion occupied by the jasper beds, the latter generally being reddened and often involved in the erupted masses. The contact of the jasper with the sandstone as well as the easy parting of the jasper bands undoubtedly facilitated the passage of the molten matter. The organic nature of the rock is indicated by the minute radiolarian skeletons in which the structure can often be seen with a pocket lense.

Scattered over the area occupied by the Golden Gate series occur prominent outcrops of a metamorphic schistose rock having a predominantly bluish tint. Owing to the general covering of soil the relations of these rocks are not always shown but where exposures are sufficiently good they appear to

be bunch-like or eliptical in form, sometimes 100 feet thick and several hundred feet long, and from this size down to those only a few inches in thickness. Where the inclosing rocks are exposed they invariably lie in contact with one of the fine grained basaltic intrusives. Glaucophane gives the characteristic bluish tint, but other minerals, such as a pearly mica, chlorite, quartz and garnet occur. These rocks possess great interest though the problems connected with their occurrence are not yet all solved. There can be little question that they have been formed through the metamorphosis of argillaceous strata in contact with igneous masses, but why this action was so irregular and intermittant it is difficult to comprehend. It is also puzzling to know why the contact rocks are invariably associated with a certain type of the pre-Cretaceous basic intrusives and not with others, such as the peridotites. The exceeding abundance of the contact rocks through those areas of the Golden Gate series where the old eruptives are the most numerous, indicates plainly that the most if not all the latter are of subsequent origin.

CRETACEOUS PERIOD.

Knoxville Beds.—The rocks of lower Cretaceous age are now confined to the Santa Lucia range, although once probably much more extensive. They form an almost continuous strip from the head of the Corral de Piedra Creek on the south slope of the Santa Lucia range northwest for a distance of over twenty miles. North of Cuesta Pass they widen out forming for a number of miles nearly the whole of the brush-covered mountains between the two crests of the range. The structure of this portion is synclinal and seems to be due to the intrusion of great masses of diabase along its edges and which form the double crests referred to. The beds are perhaps 3000 feet thick and consist of dark shales and thin bedded sandstones closely resembling those of the same age in other parts of the state. Several thin layers of pebbly conglomerate occur, one being at the base and containing numerous pebbles of jasper and other silicious rocks.

The genus *Aucella* is well represented through the lower and middle portion of the shales, but the upper portion appears to be barren of life.

The nonconformity with the underlying Golden Gate series is most marked, not only by the discordance in dip but through much less distortion of the upper beds and the entire absence of the intrusives so characteristic of the lower series. Although so much evidence exists of a break between these two groups of rocks, its real magnitude does not yet seem to be appreciated by geologists as it ought. The more the question is studied the more its importance must appeal to geologists.

Chico formation.— The upper portion of the Shasta group known as the Horsetown beds was not recognized within the area under discussion and it seems probable from the stratigraphic relations existing between the Knoxville beds and the Chico formation that it is absent. The Chico occurs in two widely separated localities. The most important one forms a belt one to two miles wide and many miles long on the northern slope of the Santa Lucia range. The other is a strip about the same width extending along the coast from a point six miles west of Cayucos, northwestward for about eighteen miles. In both areas the rock consists almost wholly of sandstone. Fossils are not abundant but they were found in sufficient numbers in the Santa Lucia Mountains to demonstrate the age of the formation. In the latter locality the sandstone terminates downward in a conglomerate which is in places 100 feet thick, resting either upon the Knoxville shales or the Golden Gate series. The sandstones on the coast rest upon the Golden Gate series exclusively. The relation to the Knoxville shales was carefully examined at many points along the northern slope of the Santa Lucia Mountains and a conclusion reached which is in accord with one already published,[1] namely, that the lower and upper Cretaceous are, in this region at least, separated by a nonconformity. This is shown by the marked discordance in the dip between the two and the extension of the upper across the

[1] JOUR. GEOL., Vol. III, p. 426.

strike of the lower, as well as by the fact that the upper rests indiscriminately upon either the lower Cretaceous or the Golden Gate series. A nonconformity is also indicated by the fact that where the serpentine in this region, as in other portions of the Coast Ranges, comes in contact with the lower Cretaceous, the relation is one of intrusion while the Chico rests upon it undisturbed. The lower Cretaceous was intruded by the peridotite, upturned and eroded before the deposition of the Chico.

TERTIARY PERIOD.

Strata of Middle Tertiary age are widely distributed over this region and probably once covered nearly the whole of it. The Eocene on the contrary is entirely absent although extensively developed to the southeast in Santa Barbara and Ventura counties. It seems probable that during early Tertiary time this portion of the Coast Ranges was above water for if the Eocene ever had existed here it would be reasonable to expect some remnant of it would be met with. The Lower, Middle, and Upper Neocene are all represented.

NEOCENE.

Monterey series (*Lower Neocene*).—With the beginning of the Neocene a subsidance commenced and continued through, or nearly through the Miocene. Finally, almost the whole Coast Range region was submerged and a thickness of rocks in many places of more than 7000 feet was deposited. The most characteristic feature of the series is the bituminous shales. They form its upper portion and reach a thickness of 5000 feet. Below them are limestones, clays, volcanic ash, sandstones and conglomerates. Erosion has removed a large part of these rocks, but the similarity in succession of the characteristic horizons at various points in the area surveyed points to the fact of their former continuity.

The sandstones and conglomerates at the bottom of the series are most prominently developed in the region lying east of the Rinconada Valley, between it and the main granite range.

The thickness of these beds is remarkable, being 6000 to 8000 feet. They occupy the same position with reference to the bituminous shales as similar beds on the upper San Antonio River.

The volcanic ash forms a fairly constant horizon over nearly the whole of the region mapped. Several different centers of volcanic action seem to have existed in this region shortly after the beginning of the Miocene. In the mountains south of San Luis Obispo the ash has a thickness of fully 800 feet, while beginning near the Lion rock at the western end of the San Luis range this bed of volcanic ash extends easterly along the southern slope for a distance of over thirty miles. Near the centers of eruption the fragments are coarse, but farther away the deposit consists of frothy pumice, and in places occurring in beds of glass as fine as dust. On Old creek a small flow of banded rhyolite is associated with the fragmental material. It seems probable from the large amount of ash and small amount of massive lava that the eruptions were of an explosive nature and took place at or beneath the surface of the sea. This is the same eruption as that indicated at Point Sal.[1]

The bituminous shales and flints form the uppermost member of the Monterey series. They constitute the main portion of the San Luis range and that portion of the Santa Lucia range lying east of Cuesta Pass. They also underlie the younger formations in the upper Salinas Valley. This formation measured in both ranges appears to reach the enormous thickness of 5000 feet. It consists almost exclusively of a thin banded silicious shale which over extensive areas has been changed to a flint. Much remains to be done in a detailed study of these shales, although it has been quite certainly proved that they are largely of organic origin.[2] The shales are generally more or less impregnated with bituminous matter, and it appears to be reasonably certain that they constitute the main source of the oil and asphaltum which is so widely distributed through the Coast Ranges. Springs of thick oil and sulphurous water issue from

[1] Bull. Dept. of Geol., University of California, Vol. II, p. 16.

[2] Bull. Dept. of Geol., University of California, Vol. II, p. 13.

them, and when covered by porous beds vast deposits of bitumen have been formed.

San Pablo formation (*Middle Neocene*).—Overlying the Monterey series unconformably is a series of soft sandstones, diato-

Nonconformity between the San Pablo formation and the Monterey series. Ocean cliffs near Pismo.

maceous beds, and some flinty shales. It forms the eastern extension of the San Luis range between San Luis Obispo and the ocean, as well as a considerable area in the upper Salinas Valley. In the latter region it is filled with fossils which indicate the Middle Neocene, but to be more exact, whether the uppermost Miocene or the lowest Pliocene is as yet undetermined. Dr. Merriam has in a recent publication[1] described a series of strata on the southern shore of San Pablo Bay containing a similar fauna which he believes represents a distinct and

[1] Bull. Dept. of Geol., University of California, Vol. II, No. 4.

hitherto unrecognized palæontologic group. These strata it appears overlie those of the Contra Costa county Miocene with indications of a nonconformity, but the fossils collected from them by earlier palæontologists have in some cases been referred to the Miocene, in others to the Pliocene. To this series of rocks Dr. Merriam has given the name San Pablo formation. As the group of rocks in the southern Coast Ranges is undoubtedly the equivalent of those on San Pablo Bay, the latter name will be extended to it. In the San Luis Obispo region the nonconformity of this series of rocks with the Monterey series is distinctly shown in many places. Good examples appear along the coast north of Pismo as well as in the vicinity of Santa Margarita in the upper Salinas Valley. The basal conglomerates of the San Pablo formation, often but little disturbed, lap over on the more highly tilted and disturbed shales and contain many fragments of the latter often filled with mollusk borings. A great interval of time must have separated the deposition of the San Pablo formation from that of the bituminous shales, for the former formation extends over the shales in places and rests directly on the Golden Gate series. This time must have been sufficient for the erosion of at least 5000 feet of the Monterey series. During this time also the chief chemical change was wrought in the bituminous shales, for pebbles of the flinty altered shales occur at the base of the San Pablo formation in exactly the same condition as the shales on which this formation rests.

The discovery by Dr. Merriam of the marked palæontologic differentiation of the fauna of this group of rocks is an important addition to our knowledge of the younger formations of the Coast Ranges. That it is not a local condition is shown by the results reached by the writer along different lines and wholly independently. The pronounced nonconformity so clearly apparent in the San Luis Obispo region is confirmatory of the palæontologic investigations and firmly establishes the validity of the new formation. Its fauna is certainly older than that of the Merced beds, and if it should prove to be the upper-

most Miocene the rocks of that age in California can no longer be looked upon as forming a unit but separated into two divisions by an extended period of elevation and erosion. This point established other and puzzling questions relating to the Miocene and Pliocene are in a fair way to be cleared up.

Paso Robles formation.—The later Neocene in this portion of the Coast Ranges consists of a very extensive series of beds having apparently a fresh-water origin. They fill the Salinas Valley as far up as Atascadero, lapping over unconformably upon the upturned and sharply folded San Pablo formation. They are characteristically exposed about the town of Paso Robles, hence the designation. From Paso Robles the beds extend westward toward the Santa Lucia Mountains, and for many miles north and east of that place, filling the valley of the Estrella and its tributaries, and may reach into the Great Valley. The formation consists of conglomerates, sandy and marly clays, as a general thing, but slightly consolidated. The great extent of this formation in the drainage area of the upper Salinas River, its peculiar character and total absence of marine organisms, or organisms of any kind as far as observed, make it appear probable that it is of fresh-water origin, and for these reasons, though it is possibly contemporanous with the marine formation known as the Merced beds, it should be given a distinct name. The strata are generally almost horizontal, but along the Salinas River in particular they are tilted and faulted. Beds of the same character overlie the San Pablo formation in the vicinity of Arroyo Grande.

Fresh-water beds of Pliocene age are widely distributed through the Coast Ranges.[1] Those in the valleys of the upper San Benito and Salinas have been referred to by Lawson as Pliocene delta deposits,[2] and considered the equivalent of the Merced beds. While the latter view is probably correct, there is no reason to consider them delta deposits; on the contrary, they

[1] Monograph No. XIII, U. S. G. S., p. 238; Bull. Dept. of Geol., Univ. of Cal., Vol. I, p. 152; Bull. Dept. of Geol., Univ. of Cal., Vol. I, p. 363.

[2] Bull. Dept. of Geol., Univ. Cal., Vol. I, p. 153.

have decidedly the character of fresh-water lake beds, and there is no reason to believe that they were ever connected with the Merced beds.

PLEISTOCENE.

Under this designation are included the terrace formations, blown sand, stream gravels, and alluvial bottoms. These were not all formed at once, but represent a complicated history. The terrace formations belong to the oldest division. The most extensive area included under this head embraces a great stretch of sandy mesas and hills between the mouth of the Arroyo-Grande Creek and the Santa Maria River.

The coast, almost everywhere more or less distinctly terraced, forms an elevation of about ten feet above mean tide up to 750 feet. In addition terrace-like effects were noted upon the southern slope of the Santa Lucia range at elevations of 1000, 1400, and 1700 feet, aneroid measurements. In many places along the upper Salinas there are beautiful examples of river terraces cut upon the Paso Robles formation.

IGNEOUS ROCKS.

The igneous rocks of the San Luis Obispo region form one of the most interesting features of that field. Intrusives and surface flows are numerous, especially the former. They are so abundant in the Golden Gate series as in many places to form fully one-third of the surface exposures. The extensive sheets of diabase and peridotite appeared during the Cretaceous, and a great variety, though of much lesser extent, during the Miocene. The age of the andesite and dacite granophyre forming the buttes reaching from San Luis Obispo to Morro Bay cannot be determined with certainty. It certainly antedates the peridotites which appeared at the close of the Knoxville and may be of pre-Cretaceous age.

The igneous rocks, all taken together, show a great range in chemical and mineralogical composition, with examples of rare and interesting types. They have not yet been thoroughly

studied, and no detailed description will be attempted in the present paper.

In the following outline the main types of igneous rocks occurring in this field will be given and arranged in groups according to age:

Granite,	Earlier than the Jurassic.
Basalt, intrusives and surface flows, Peridotite, Diabase,	Earlier than the Cretaceous. Intrusive in Golden Gate series.
Dacite granophyre, Andesite granophyre,	Earlier than the Middle Cretaceous. Possibly pre-Cretaceous. Intrusive in Golden Gate series.
Diabase,	Earlier than the Chico. Intrusive in Knoxville beds.
Peridotite serpentine and related feldspathic rocks, including diabase, gabbro, and pyroxenite,	Earlier than the Chico. Intrusive in the Knoxville and preceding diabase.
Rhyolite, Augite teschenite, and olivine diabase, Quartz basalt, Basalt,	All probably earlier than San Pablo formation. Intrusive in Monterey series.

The granite covers a large extent of country east of the upper Salinas River. It is remarkably uniform, consisting of quartz, biotite, orthoclase, plagioclase, and titantite. Large orthoclase phenocrysts give a porphyritic aspect in places. Numerous dikes of a finer-grained granite intersect it. Nothing is known concerning the age of the granite, save that it forms the southeastern continuation of the crystalline axis of western Monterey county, on which the Golden Gate series rests with a basal conglomerate. It is certainly much older than the Jurassic.

The dikes of basic pre-Cretaceous intrusives in the Golden Gate series are almost innumerable, and, as they are generally much altered, weather away readily and are difficult to map accurately. Owing to the disturbances which the series has undergone, it is also almost impossible to distinguish in all cases the surface basalts from the dikes with similar appearance. The

greater number of the dikes are fine grained and amygdaloidal on the edges. Dikes of diabase are also numerous. The rock having the most limited distribution is the peridotite. This is not as much decomposed as might be expected, considering its

Morro Rock (dacite granophyre) on the coast at mouth of Morro Bay.

age, and consists of olivine, a rhombic pyroxene, and sometimes augite and a little feldspar. The dikes follow the strike of the rocks, and are more abundant in the jasper horizons. Contemporaneous flows were not recognized with certainty, and it is the writer's opinion that they are more rare upon the San Francisco peninsula than Lawson has supposed. They are not all of the same age. The surface flows did not take place until after the Golden Gate series had been upturned and planed off. This is shown in the hills east of Los Osos Valley.

The dacite and andesite granophyres are strikingly interesting rocks. The occur as roundish or lenticular plugs forming the large buttes, besides many small ones, between San Luis Obispo and Morro Bay. The dacite variety is confined to sev-

eral of the northern ones, the andesite to those nearer San Luis Obispo. The important constituents of the former are quartz, biotite, and an acid plagioclase feldspar ; of the latter labradorite, biotite, and enstatite, as porphyritic constituents in a granular base. Morro Rock is the most striking topographic feature on the coast of California.

The diabase intrusive in the Knoxville beds has a character different from any other rocks in the region under investigation. It is grayish in color, fine grained, and amygdaloidal upon the edges. It has come up in great dikes or sheets on either side of the main Knoxville area, throwing the latter into a synclinal trough. It extends northwest from Cuesta Pass for many miles, and is quite uniform save for local gabbroitic variations.

The peridotites and related feldspathic rocks of the Coast Ranges are well known. The great body of this rock in the San Luis Obispo region has been changed to serpentine. It consisted originally of olivine and augite. Local variations rich in feldspar occur along the Santa Lucia range forming diabase and gabbro. The feldspathic facies is quite extensively developed not only upon the borders of the great serpentine area north of San Luis Opispo, but also in many places as apparently independent intrusions. From their similarity in character it is easy to see, however, that all these rocks are genetically related. The serpentine has the usual sheet or lense-like character conformable to the dip and strike of the inclosing rocks, which usually stand very steeply.

The igneous rocks of Tertiary age have a great range in chemical and mineralogical composition. The succession of these rocks was only partly determined. The oldest is the rhyolite of which there are two varieties. One contains free quarts and occurs as a very limited surface flow, being mostly represented by tuffs. The other has the form of long, narrow sheets intruded near the base of the Miocene, and contains no free quartz, but an abundance of plagioclase phenocrysts. The ash which is so widespread at this horizon appears to be connected with rhyolite eruptions, but these particular sheets are

probably of later date, as they are clearly not surface flows. The ash reaches in places a thickness of many hundreds of feet, and in the hills south of San Luis Obispo passes downward into an agglomerate of bowlders of perlitic glass, many of them of large size.

The surface flow of rhyolite on Old Creek is very interesting. It is only a few feet in thickness and imbedded in a great mass of tuffs of the same character. The sheet terminates at one edge in flattened nodular masses from one-half inch to eight inches in diameter. Some of these are entirely free, others more or less connected in the plane of flow. Superficially many of these nodules appear like concretions or large spherulites, but their internal character is entirely different. The flowage lines pass through them regularly without regard to the shape of the surface, and the interior appears to have shrunken away from the center, from which radiating cracks either empty or filled with chalcedony spread toward the outside. These cracks break across the banding with but little disturbance of the latter. They do not appear to be real spherulites and the field relations suggest that their peculiar character may be due to sudden cooling under water.

The augite teschenite and olivine diabase form two generally distinct variations of one magma. The former rock contains varying proportions of analcite and its alteration products, augite and a basic feldspar. The typical examples are rather light colored rocks, but with the appearance of olivine and a decrease of feldspar and analcite the rock becomes very dark and basic looking. Some of the olivine diabase contains so little feldspar that it might with almost as much propriety be termed a peridotite. These rocks are among the most interesting of any yet discovered in the Coast Ranges, and as far as is yet known the augite-teschenite is confined to Santa Barbara and San Luis Obispo counties. It has been described in former papers.[1] Not only is it petrographically interesting, but remarkable for its structural relations to the Miocene in which it is intruded.

[1] Bull. Depart. of Geol., Univ. of Cal., Vol. I, p. 273; *ibid.*, Vol. II, p. 19.

The quartz basalt occurs in the form of dikes intruded at the base of the Miocene east of Edna. The larger one is nearly continuous, following the strike of the rocks for two and one-half miles. The rock is dark and fine grained with a few scattering phenocrysts of labradorite feldspar. The most important phenocrysts are quartz scattered in a fairly uniform manner through the rock. The quartz grains show the effects of corrosion and are surrounded by augite microlites. The analysis shows that the rock has a rather low percentage of lime, but there can be no doubt that it belongs among the basalts.

Other Tertiary basalts occur on a small scale at several different points, but they have no striking features and will not be described here. It is impossible to determine the relative ages of these basic igneous rocks, although it would seem that with the exception of the rhyolite they followed the disturbances which folded the Miocene.

STRUCTURAL GEOLOGY.

Nearly all the structural features have a linear arrangement along northwest and southeast lines. The mountains are structurally synclines elevated by comparatively recent movements, the most important being faulting. This region may be divided in a general way into five crustal blocks, as follows, beginning on the north: the granite and associated rocks north of the Salinas Valley, the depression occupied by the Salinas Valley, the Santa Lucia range, the western foothills of this range and the broad valleys at its southern base, and last, the San Luis range. Each of these blocks has behaved as a unit since Miocene, or in several cases very much earlier times. All the faulting now recognizable dates from later Neocene time. The Santa Lucia range constitutes a remarkable fault block. It has been elevated, not by a single fault on each side, but in most places by several forming step faults. A fault line follows the lowest portion of the Salinas Valley, and other lines of folding and faulting are to be seen along the northern slope of the Buchon range.

One of the most striking structural features is the occurrence in the Monterey shales of the Buchon range of great bodies of bituminized sand forced into its present position during the folding which terminated the deposition of the San Pablo formation. There are two of these sand pockets or bosses north of Sycamore Springs. They occur near the ends of subordinate anticlinal folds. The largest body of sand is fully 500 feet across, elongated somewhat in the direction of the strike of the shales and with narrow dikes radiating from it. The sand has probably been forced in from beneath from the adjoining San Pablo formation, as the nose-shaped terminations of the anticlines in which the sand appears have been forced slightly over that formation.

The structural relations of some of the igneous rocks are quite remarkable. Especially is this true of those which have appeared in the Monterey series. Bodies of the teschenite and olivine diabase magmas have come up underneath this series but have rarely if ever broken completely through it. Having penetrated as far upward as the limestones or bituminous shales they have spread out between the strata in sheet form. Two remarkable cases occur north of San Luis Obispo between it and the railroad water tanks. Here are two hills, one a half mile in diameter, the other nearly a mile, rising quite abruptly from the lower rolling country and capped by a thin layer of Monterey limestone and shale. Each hill has an amphitheater-like center, the strata dipping inward from all sides but one, and from this a depression has been eroded. The peculiar topography and saucer-like structure is due in each case to a sheet of teschenite which outcrops around the steep outer slope metamorphosing the overlying rocks. From a general study of the region it seems likely that the Monterey series had already undergone disturbance and folding when these igneous rocks appeared.

One of the crests of the Santa Lucia range about 20 miles north of San Luis Obispo has on its summit a long narrow remnant of Monterey shales folded in synclinal form. For some

miles the center of this syncline has been broken through by bodies of olivine diabase. They appear as dikes or bunches which as exposed in places have lifted up and inclosed large masses of the shale.

On Old Creek there are very large sheets of the diabase, from the upper surface of which the Monterey shales have been nearly removed, as they occur only in patches here and there. These igneous masses in many respects resemble laccolites, only that instead of having arched the strata in dome form they appear as saucer-shaped sheets issuing from lines of fracture along centers of synclines.

GEOLOGICAL HISTORY.

The geological history of this region is exceedingly complicated, and in the short review following only the merest outline can be given. The earliest event of which we have any record in the Coast Ranges was the invasion of the crust by great masses of molten granite, metamorphosing the existing sediments to marbles and schists. The date of this convulsion is unknown save that it must have long antedated the Jurassic. With the beginning of the deposition of the Golden Gate series the great area of crystalline rocks which had for so long a time formed a land mass in the region of the present Coast Ranges began to subside and continued to do so with oscillatory movements until its close. Although this formation is so widespread it is essentially a near shore or shallow water formation as it consists so largely of sandstone. The conditions at times changed and the sea bottom instead of being subjected to sedimentation from the land was covered with the siliceous skeletons of radiolaria which it is believed form the main portion of the lenticular jasper beds.

With the upheaval of the series, and in some cases possibly earlier, appeared dikes and sheets of basic igneous rocks which everywhere so abundantly characterize it. After erosion had planed off the surface flows of basalt took place.

The period of the intrusion of the more acid plugs forming the line of buttes between San Luis Obispo and Morro Bay is

not exactly known. It may have taken place before the deposition of the Knoxville beds.

With the beginning of the Cretaceous the Coast Range region sank and the thin bedded sandstones and dark shales of Knoxville age were formed. They lie unconformably upon the upturned strata of the Golden Gate series and their basic intrusives.

At the close of the Knoxville a disturbance not heretofore recognized in the Coast Ranges took place and the great masses of diabase were formed which threw the beds of that age along the Santa Lucia into a synclinal form. Before the beginning of the Chico another important event took place. This was the welling up of vast bodies of peridotite, now altered to serpentine, which appear everywhere in the Coast Ranges in rocks older than the Chico. Dikes of serpentine penetrate the diabase just referred to and are therefore younger. It is then clear that the conglomerate at the base of the Chico and the nonconformity of this formation upon the Knoxville is due to a widespread disturbance resulting in an elevation of the region above the sea during a portion of the Middle Cretaceous.

The Eocene is absent from this portion of the Coast Ranges and it is legitimate to infer that the region was above water during the whole period.

Before the inauguration of the Neocene sinking commenced, and we find rocks of this period everywhere underlaid by a conglomerate formed as the sea encroached upon the land. Shortly after the beginning of the deposition of the Monterey series violent volcanic disturbances are recorded as having taken place. Local flows of rhyolite occurred and ash of that composition in the form of glass was thrown out in vast quantities and distributed over the sea for many miles. Following this the bituminous shales and limestones were formed. They consist almost wholly of organic material, the more or less blended and broken skeletons of foraminifera, diatoms, and radiolaria. A very extended period of time must have been required for the deposition of 5000 feet of these sediments which are believed to accumulate

slowly. Peculiar conditions must have existed, the sea being practically free from detrital material though the area of deposition could not have been far removed from the land.

The latest igneous action in this region probably followed the initial folding of the Monterey series preceding the deposition of the San Pablo formation, when the basalt, teschenite, and olivine diabase appeared.

After a period of elevation and prolonged erosion during which the great thickness of Monterey series was totally removed from some areas, and the shales of that period had undergone a chemical change, a subsidance began and the sandy strata of the San Pablo formation were laid down. The present configuration did not exist and this formation probably spread across the Santa Lucia range.

The discovery of the nonconformity of the San Pablo formation upon the bituminous shales (Monterey series) necessitates the addition of a correction to the diagram recently published illustrating the oscillations of the Coast Ranges.[1] Two oscillations should appear where the one is represented as separating the Miocene and Pliocene, with the understanding that the dividing line between these two periods is not at present settled.

After a deposition of at least 3000 feet of sediments, elevation and folding were experienced, terminating the San Pablo period; and the outlines of the present mountains were originated.

Marine formations of late Neocene age have not with certainty been recognized in this region. The Paso Robles formation indicates the existence of fresh-water lakes of large extent. With the close of the Neocene an upward movement was inaugurated and continued, it is believed, until the region was much higher than at present.

Following this early Pleistocene elevation a reversal took place and sinking went on until the coast was submerged to the depth of the highest terraces. With the gradual recovery from this depression the lower terraces were formed and again a point

[1] American Geologist, Vol. XX, p. 225.

was reached somewhat above the present. How much this was is not known for the mouths of all streams have been flooded by the ocean. The last movement has been one of subsidance as shown not only by the flooded stream mouths but by Morro Bay, a sheet of water whose origin can only be accounted for by the theory of a depression.

It is hoped that the foregoing discussion will convey some conception of the interesting and complicated problems encountered in the geology of the Coast Ranges.

HAROLD W. FAIRBANKS.

BERKELEY, CALIFORNIA.
June 8, 1898.

THE MIDDLE COAL MEASURES OF THE WESTERN INTERIOR COAL FIELD.

THE most important coal field west of the Mississippi, so far as present development is concerned, is that which stretches from north central Iowa across portions of Missouri, Nebraska, Kansas, Arkansas, Indian Territory, and into Texas. In recent years there has been a good deal of geological work done within this field and some of the older conceptions of its stratigraphy are being changed. It is proposed to discuss here certain problems relating especially to the northern end of the field; that portion extending from central Iowa to southwestern Kansas.

The first extensive investigations of the geology of the Iowa-Missouri coal field were those of Owen[1] who traversed the main streams crossing the region and correctly outlined its limits. He determined the base of the Coal Measures and discovered many important facts with regard to structure and general geology, but made no attempts to build up a general section nor to divide the beds into minor formations. His successors, especially Swallow, Broadhead, and White, applied themselves to this task. Swallow, in an introductory statement regarding the Coal Measures of Missouri,[2] says that they appear to be separated into three divisions by two very important sandstones. These three divisions he calls "Upper," "Middle," and "Lower Coal Series." With the change "series" to "measures" this terminology was generally followed by writers on this region up to 1893 when Keyes, having previously noted the doubtful utility of the term Middle Coal Measures,[3] suggested that the beds were better considered to form two formations which he named the Missouri and the Des Moines.[4] In the succeeding reports of

[1] Geol. Surv. Wisconsin, Iowa, and Minnesota, 1852.

[2] Geol. Surv. Missouri, I and II, p. 78, 1855.

[3] Bull. Geol. Soc. Amer., Vol. II, pp. 277-292, 1891.

[4] Iowa Geol. Surv., Vol. I, p. 85, 1893.

the Iowa and Missouri surveys the beds formerly referred to the Middle Coal Measures have been considered to form a subordinate division of the Des Moines. In Kansas, Haworth has recognized a series of formations of which he correlates the lowermost, the Cherokee shales, with the Des Moines.[1] Above the Cherokee shales and below the Erie limestone, which is at least in a general way equivalent to the Bethany limestone, are placed the Oswego and Pawnee limestones, which with the interbedded shales, would seem to be the equivalents of the Middle Coal Measures of the older classification. Since the earlier work there has been less attempt to build up general sections of the Coal Measures of this field and the tendency has been rather to emphasize the diversity of the beds and the lack of continuity of the strata.

Non-persistence of individual strata is more or less characteristic of all shore formations. It is exceedingly difficult to conceive shore conditions under which beds could be deposited without this being true. When in addition it is remembered that there is excellent evidence that the particular shore line along which the lower Coal Measures of this field were laid down was unstable and subject to change through a considerable vertical range, it will be seen that the attempt to define subordinate formations in the Coal Measures cannot well be expected to yield satisfactory results. All the minor groups which are recognized may be expected to prove of local importance only.

The beds of the upper portion of the Coal Measures, however, beginning with the base of the Missourian formation, indicate that they were found under radically different conditions. Individual bands of limestone, ten feet and less in thickness, may be traced step by step for one hundred or two hundred miles.[2] Bands of black shale, the "slate" of the miners, a foot or less in thickness, seams of impure coal measured in inches only, and thin ledges of impure black limestone of the type elsewhere

[1] Univ. Geol. Surv. Kansas, Vol. I, p. 150, 1896.

[2] Bethany Limestone at Bethany, Mo., H. Foster Bain; Am. Jour. Sci., (4), Vol. V, pp. 433–439, 1898.

least constant in character, maintain themselves over areas of many miles. All of the beds, whether they be limestone made up of beach-rolled fragments, shale suggesting the infra-littoral zone of deposition, or the pure heavy limestone probably marking open sea deposition, are of such uniformity as to force the conclusion that only under conditions of widespread stability could they have been formed. In Kansas and the southern portion of the field there was an important recurrence of shore conditions later in Missourian time. In the portion of the field immediately under discussion, however, this later period of shore conditions is much less important and the uniformity which marks the opening of the Missourian, seems to have persisted throughout the period.

The change from the condition obtaining in the early Des Moines to those present when the Missourian began was a gradual one. During the former period there was no uniformity anywhere, and the field was broken up into a multitude of minor basins of deposition each the theater of an individual sequence of events, while during the latter the whole of southwestern Iowa, northwestern Missouri, eastern Kansas, and probably an even larger area, acted as a unit. The turbulent conditions of the earlier period became merged into the uniform conditions of the later one. Gradually larger and larger areas came to act together and local sequences came to have a wider and wider applicability. It is the beds of this intermediate period which were recognized as the Middle Coal Measures and in the absence of unconformity it will be seen that there is *a priori* reason to expect a series of beds intermediate in character and position between the typical Des Moines and the recognized base of the Missourian. All who have written on the subject have recognized that the Coal Measures mark a continuous sequence of deposition with only local breaks. Any divisions must be more or less arbitrarily established though they may be none the less useful.

The earliest complete section of the Middle Coal Measures published was that of Swallow.[1] A comparison of the plates

[1] Geol. Surv. Missouri, I and II, pp. 82–86, 1855.

given by him with the general section published by White[1] shows a great similarity in the character of the beds, and parts of his section even show a general similarity of sequence. The section given by White was based largely upon investigations carried on along the Raccoon River in central Iowa, a region recently restudied by the present Iowa survey. The section made out in the course of the present work is much the same as a portion of that earlier published. There are, however, certain changes of importance. The upper part as originally published[2] is essentially as given below, the original section numbers being retained.

		Feet
44.	Arenaceous shale and sandstone, - - -	10
43.	Bituminous shale, - - - - - - -	4
42.	Lonsdale coal, - - - - - - - -	2
41.	Shales, light and blue, - - - - - - -	15
40.	Limestone, - - - - - - - -	5
39.	Shales, light red, blue, arenaceous, - - -	30
38.	Limestone, impure, dark blue, - - - -	2
37.	Bituminous shale and coal, - - - - - -	3
36.	Shales, yellow and blue, - - - - -	5
35.	Sandstone, - - - - - - - - -	10
34.	Shales arenaceous, yellow and blue, - - -	15
33.	Marshall coal, - - - - - - - -	1½
32.	Shales, blue and yellow, - - - - -	8
31.	Limestone, impure, fragmentary, bluish buff, -	2

These beds vary more or less in thickness, but maintain the same sequence over a considerable area.[3] The Lonsdale coal is still worked at the type locality and lies about thirty feet below the base of the Bethany limestone. The heavy sandstone, No. 35, is well exposed and easily recognized. Below the section as given there is a sequence composed mainly of shales estimated to be about 150 feet thick. Below this in turn is a series almost identical with that just quoted, but in which

[1] Geol. of Iowa, Vol. I, pp. 272, 1870.

[2] WHITE, loc. cit.

[3] Geol. Guthrie county, Iowa, Geol. Surv., VII, pp. 428–446, 1897; Geol. Madison county, *ibid.*, pp. 504–509; Geol. Dallas county, *ibid.*, VIII, pp. 78–82, 1898.

the coal seams are named Wheeler, Panora, and Lacona respectively. One of the results of the recent work has been to show that this presumed lower sequence is in fact a repetition of the upper portion, brought about by gentle folding.

In following down the South Raccoon River and many of its tributaries the beds already enumerated are easily recognized.[1] A portion of the section is exposed upon Middle Raccoon southwest of Linden, where it is seen to be essentially the same as originally given by St. John.[2] According to the interpretation of that author the beds found in passing both up and down the river from this point were lower. Below the section already quoted he placed a thickness of 145 feet of sandy and variegated shales, and below these a series including three seams of coal and with a sequence remarkably similar to that found above the shales.[3] This hypothesis would require that the beds should rise between Panora and Linden enough not only to compensate for the fall of the stream but to throw high above the river strata deeply buried at the latter point. All dips in the region are slight and the one required here would be greater than any known to be present. Furthermore, recent studies show that the dip from Panora north is in exactly the opposite direction. It seems accordingly that the beds at Panora are to be correlated with the section already given rather than placed below it.

Traveling down the Middle Raccoon the beds rise to Redfield, at which point a thick, massive sandstone fifty feet thick is exposed below them. Below Redfield the sandstone declines and the same sequence as was seen at Linden may be made out.[4] In the southeastern corner of the county the lower portion of the section previously quoted is present overlying a mass of variegated shales. These shales are seen in Polk county, east of Dallas, and only the upper part presents any evidence of regularity. They extend down to the base of the Coal Measures and contain the bulk of the workable coal. The portion

[1] Geol. Guthrie county, pp. 436–437.

[2] See Geology of Guthrie county, p. 430.

[3] See for comparison, Geol. Guthrie county, p. 429.

[4] Geol. Dallas county, pp. 64–67.

which is more or less regular in sequence does not correspond to the lower portion of the Middle Measures as originally described,[1] but shows very different succession.

The Des Moines beds, then, in the central portion of the state consist of a thick mass of shales and sandstones, showing no definite order of arrangement which may be recognized over any considerable area, covered by more regular sequence of which the upper portion may be recognized over a considerable area; but as one travels south two changes take place. (1) The upper member of the section, No. 44, thickness from barely thirty feet on the South Raccoon to over seventy feet on Middle River near Winterset. (2) The various members of the section thin out and are replaced until in the southeastern portion of Madison county none of them can be made out. The section immediately below the Bethany limestone in the latter region is given below. It will be noticed that while none of the beds of the previous section can be recognized, the general character of the strata is the same.

	Feet	Inches
22. Shales, drab, argillaceous, with abundant *Derbya crassa*, *Chonetes*, probably *Chonetes parvus* Shum, at the top,	12	
21. Shales, red, argillaceous,	3	
20. Limestone, fragmental, earthly, with bits of fossils,		2
19. Shale, blue to green, argillaceous, grading into red below,	3	
18. Shales, blue to green, sandy, with nodular segregations of limestone,	12	
17. Shales, blue, calcareous,	12	
16. Limestone, compact,		2
15. Limestone, fragmental, loose, with young *Chonetes mesoloba*,		10
14. Limestone, fragmental, but firmly cemented, reddish color, with *Spirifer cameratus* and *Productus costatus*,	1	
13. Shales, green, argillaceous,	29	
12. Limestone, blue to black, in two ledges, with *Spirifer cameratus*, *Rhynchonella* and *Productus*,	1	
11. Shale, carbonaceous,	2	
10. Shale, clayey, drab,	1	

[1] Geol. Polk county, Iowa Geol. Surv., Vol. VII, pp. 302–310, and Geol. Iowa (White), Vol. I, pp. 272–283.

	Feet	Inches
9. Shale, yellow, sandy, with marked horizontal bedding planes, - - - - - - - - - -	4	
8. Shales, black to drab, carbonaceous, - - - -		6
7. Limestone, nodular, sandy, with *Productus cora*, *Chonetes mesoloba* and *Athyris subtilita*, - - - - - -	1	4
6. Shale, gray, sandy, - - - - - - - -	3	
5. Limestone, similar to number 7, - - - - -		10
4. Shale, clayey, drab to blue, - - - - - -		10
3. Shale, carbonaceous, - - - - - - -	1	
2. Limestone, thin bedded, leaf-like in texture, with *Productus muricatus*, *Chonetes mesoloba*, *Derbya crassa* and *Productus costatus*, - - - - - - - -		3
1. Clay, green, - - - - - - - - - -	3	

South from here in Clark and Lucas counties the work has not yet been carried on in sufficient detail to allow a general section to be made out. It is, however, known that there are in the region strata of the same general type as those found in Madison, Dallas and Guthrie counties, though probably detailed correlation will be impossible.

Along the southern border of the state the Des Moines beds outcrop from the Mississippi River west to Decatur county, where they become buried beneath the Bethany. As far west as the Chariton River the beds may be referred unhesitatingly to the lower division, corresponding, as noted above, with the Cherokee shales. Their character is shown in exposures and mine sections along the Chicago, Milwaukee and St. Paul Railway from Ottumwa southwest.[1] Above these is a formation, including several limestone beds and one widely worked seam of coal, which has been called the Appanoose formation.[2] In general character these strata correspond to those seen farther north at the same horizon. A generalized section is given below:

	Feet	Inches
17. Limestone, gray, subcrystalline, seen in the railway cut near Anchor No. 1 mine at Centerville, and known among the miners as the "floating rock," - - - - -	2–4	
16. Shale, argillaceous, color variable, - - - -	12–30	

[1] Iowa Geol. Surv., Vol. V, Pl. XIV. [2] Iowa Geol. Surv., Vol. V, pp. 378-394.

	Feet	Inches
15. Limestone, heavy ledges, exposed along Manson branch and Cooper Creek at Centerville, as well as at numerous other points in the county, the "fifty-foot limestone,"	4–10	
14. Shale, argillaceous, blue and red in color, - -	14	
13. Shale, arenaceous, frequently forming a well defined sandstone, as in boring No. 3 (No. 13), and the Rock Valley shaft, - - - - - - - - -	8	
12. Shale, argillaceous, blue to gray, - - - -	10	
11. Limestone, somewhat variable in thickness; exposed along the C., M. & St. P. railway, between Mystic and Brazil, known as the "seventeen-foot limestone" or "little rock," - - - - - - - - -	1–3	
10. Shale, sometimes gray, frequently bituminous and pyritiferous, - - - - - - - - -	7	
9. Limestone, sometimes gray, and coarsely sub-crystalline as at the Lodwick mine, Mystic; sometimes fine-grained, bituminous, and grading into the shales above and below, as at the Thistle mine, Cincinnati; known as the "cap rock," - - - - - - - - - -	2–4	
8. Shale, usually bituminous, and known as "slate;" occasionally in part soft and clay-like, then known as clod; at times heavy and homogeneous non-fissile, in which form it is known as "black bat," - - - -	1–3	
7. Coal, upper bench, usually, - - - - -	1	8–10
6. Clay parting "mud band," - - - - -		2– 3
5. Coal, lower bench, usually, - - - - -		8–10
4. Clay parting the "dutchman," - - - -		½
3. Coal, frequently not so pure, - - - - -		2– 3
2. Fire clay, - - - - - - - - -	1–6	
1. Limestone, "bottom rock," well exposed along Walnut Creek at Mystic, - - - - - - - -	3	6

This section was first made out in 1893 and published in the following year.[1] It was not, however, until 1896 that the name Appanoose was applied to the beds. At this time[2] they were defined as a subdivision of the Des Moines formation and sections were given illustrating their relations to the underlying and overlying strata. Above the Appanoose formation there is

[1] Amer. Geol., XIII, 407–411; Proc. Iowa Acad. Sci., Vol. I, Pt. IV, 33–36; Iowa Geol. Surv., II, 407.

[2] Iowa Geol. Surv., V, 378–394.

at one point an unconformable conglomerate.[1] Little is known of this formation, but it seems to be essentially local. The beds between the upper member of the Appanoose, the "floating rock" of the miners and the lowermost member of the Bethany as shown in Decatur county are but infrequently exposed and little is known concerning them. If one may judge from the topography and the infrequent exposures, the intervening beds are shales, predominantly sandy.

The three Iowa sections from the St. Louis limestone to the Bethany may be summarized as below:

Northern Section: Jasper, Polk, Dallas, and Guthrie counties	Feet	Middle Section: Monroe, Lucas, and Clark counties	Feet	Southern Section: Van Buren, Davis, Appanoose, Wayne, and Decatur counties	Feet
3. Sandy shales not to be separated from the underlying formation,	30	3. Beds covered; probably sandy shales,	50–70	3. Sandy shales, only partially exposed, (Chariton Conglomerate, local.)	75
2. Shales, limestone, three coal beds, upper portion of old Middle Coal Measures, -	100	2. Equivalents, section not yet made out,	100	2. Appanoose beds, -	100
1. Shales, heavy sandstone and non-persistent but thicker coal beds, -	400–500	1. Equivalent and similar beds, -	200–400	1. Equivalent and similar beds, -	400–600

The lowermost division is clearly the equivalent of the Cherokee shales of Kansas. The variation in its thickness is due to the erosion unconformity between it and the underlying St. Louis limestone. The middle division exhibits the same general characteristics of thin persistent limestone and coal

[1] Loc. cit., pp. 394–398.

beds throughout the state but varies in detail so much that it is impossible to correlate the individual beds of the north, middle and south sections. The uppermost beds represent a recurrence of the type of sedimentation shown by the lower member and present a notable thickening to the south. Indeed this member is practically absent at the northern end of the area so that the Iowan field includes apparently only the northern half of an immense lense of sandy material, intercalated between the limestones of the Bethany and the Appanoose formations.

As has been pointed out by Keyes[1] there is a close correspondence between the sections made out in Iowa, Missouri, and Kansas. These may be summarized as below.

	Iowa	Missouri	Kansas
3.	No name	Pleasanton	Pleasanton
2.	Appanoose	Henrietta	Pawnee Oswego
1.	Cherokee	Cherokee	Cherokee

The Middle Coal Measures as originally defined included the two upper divisions noted here. Swallow[2] recognized along the Missouri and at the top of his section some thirty feet of sandy shales. White and St. John found about the same thickness along the Raccoon River. Between these two points it is now known that the sandy member attains a considerable thickness and becomes sufficiently distinct to perhaps warrant giving it a separate designation. For this division Haworth's term Pleasanton[3] seems to have precedence if the beds are to be considered as distinct from the next lower formation.

The middle member of the above table includes the major

[1] Proc. Iowa Acad. Sci., Vol. IV, pp. 22–25, 1897.

[2] Op. cit., pp. 82–83. [3] Kan. Univ. Quart., Vol. II, p. 274, 1895.

portion of the old Middle Coal Measures. As now defined, this median member forms a single well-defined formation, with certain uniform characteristics, and may be well recognized as a distinct unit. Toward the north limestones are thinner and more numerous, while to the south they come together and thicken, until in Kansas they form two well marked beds to which Haworth has given the names Oswego and Pawnee. The Henrietta limestone of Marbut[1] in southwestern Missouri seems to include these two limestones with an intervening shale bed. The whole forms a well defined escarpment which Marbut has traced across the southwestern portion of that state. No detailed section of the Henrietta formation has yet been published, so that the correlation of its individual beds cannot yet be made. In north central Missouri the formation seems to resemble more closely the beds found in southern Iowa, since the Mystic coal is widely recognized in Putnam, Schuyler, and Adair counties.[2] The whole series of sections would seem to indicate a gradual change of character, from the near shore beds of the Raccoon River section to the off shore beds of Kansas. This change is very gradual as the series of sections is taken parallel to the strike.

For this median member of the Des Moines series no good term has yet been proposed. The designations used in Kansas refer to individual parts of the formation. The name Henrietta and Appanose have been applied to distinctive phases of the formation. No general term has yet been used for the Raccoon River beds. If it is thought best to apply to the whole formation one of the names already in use, it would seem that Appanoose would have precedence as being first clearly defined and located. There are, however, objections to this since the Appanoose formation as now defined is coextensive with an important coal bed and hence has a definite economic significance. Henrietta has been used in the general sense here suggested,[3]

[1] Missouri Geol. Surv., Vol. X, p. 44, 1896.

[2] Proc. Iowa Acad. Sci., Vol. I, Pt. IV, p. 36, 1894.

[3] Keyes, Proc. Iowa Acad. Sci., IV, 23; and Eng. Mining Jour., Feb. 26, 1898, p. 254.

but if this usage is to be adopted it would seem desirable that the formation be properly defined and some general section of it, as typically exposed, be given. Since, however, Henrietta was first applied to a distinctive phase of the formation, that displayed in southwestern Missouri, it will probably be found better in the end to adopt a general term for the whole region, retaining the terms now in use, Pawnee, Oswego, Henrietta, Appanoose, and Raccoon River beds, for local use. This is the more advisable, since, while the beds show certain general characters common to all and are probably of essentially contemporaneous origin, they really contain the record of deposition in four and perhaps more essentially distinct minor geological provinces.

H. Foster Bain.
A. G. Leonard.

KETTLES IN GLACIAL LAKE DELTAS.[1]

THE object of this brief paper is to describe a remarkable basin in a glacial-lake delta in western New York, and to discuss similar phenomena in general only so far as to throw light upon this particular case.

Between Canandaigua and Seneca valleys lie three north and south valleys which hold no lakes. The most westerly of these is the Middlesex or West River Valley, which drains south into the head of Canandaigua Lake. The next is the valley of Flint Creek, which flows north. Eastward is another deep valley which drains south into Keuka Lake, at Branchport. Upon the west side of the middle one of these three lakeless valleys, the Flint Creek Valley, lies the little village of Potter. Close behind the village is a conspicuous plateau of stony gravel rising 250 feet above the valley plain. In the middle of this ancient plain occurs the singular basin herein described.

This delta is one of the many phenomena which record the intricate and interesting history of the glacial waters in the "Finger Lake" region. The events leading up to its formation seem to be as follows: During the recession of the front of the ice-sheet there came a time when the southern or upper end of each north-sloping valley was free of ice, and the impounded waters were forced into southward flow.[2]

In the Keuka Valley the glacial waters were at first compelled to overflow directly south into the Cohocton River at Bath, but they soon found a somewhat lower outlet across the eastern rim of the basin through the site of Wayne village and the chain of small lakes. These waters have been named the

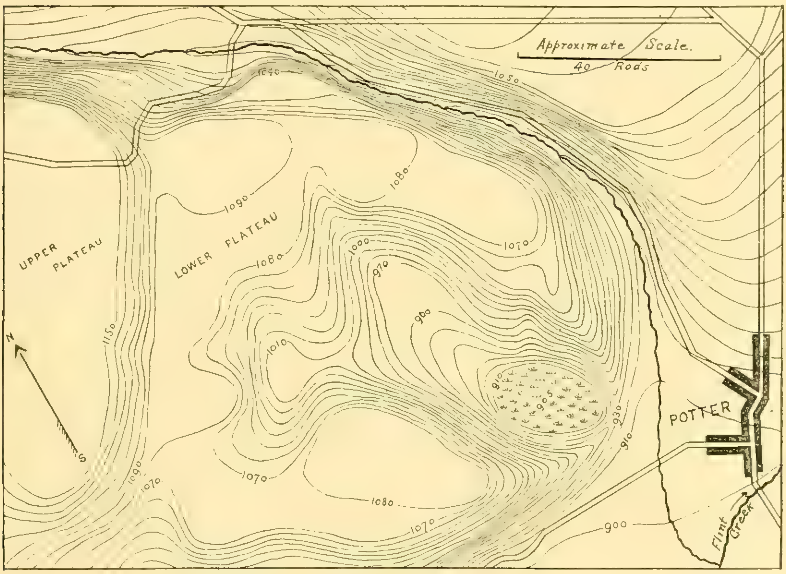
[1] Presented before the American Association for the Advancement of Science, August 25, 1898.

[2] Papers descriptive of the glacial lakes of western-central New York may be found in the Bulletin of the Geological Society of America, Vol. VI, pp. 353–374; Vol. VII, pp. 449–452; Vol. VIII, pp. 269–284.

Hammondsport Lake. Probably somewhat later the southern end of the Canandaigua Valley was occupied by glacial waters, the Naples Lake, which have left a well defined overflow channel near Atlanta. At this level the Naples Lake flooded as much of the Honeoye Valley upon the west, and the West River or Middlesex Valley upon the east, as the recession of the ice-sheet had left open. With further removal of the ice-front a lower outlet for the Naples Lake was uncovered on the eastern border of the Middlesex Valley, about two miles northeast of Middlesex village, and a channel was cut by the escaping waters leading east toward Potter. It was the stream which cut this channel, and drained the waters of the Canandaigua-Middlesex valleys into the Hammondsport Lake, that built the Potter Delta. The ravine is about one mile long. Its depth will average about 100 feet, mostly in shale, with a width at the bottom of about 100 feet, and a uniform gentle grade, with a total fall of about 30 feet. At present it carries no stream. The lower end of this channel is not far above the level of the valley plain of Flint Creek, which indicates that the channel was effective even after the glacial waters in the Flint Creek Valley had found an outlet not far higher than the present plain. Indeed, the gravel and sand plain of the broad valley bottom is probably the filling during the last phase of the glacial waters. The delta represents the earlier deposits at the mouth of the down-cutting stream in the higher or Hammondsport Lake. There are two prominent levels on the delta. Aneroid measurements, using the Lehigh Valley Railroad at Middlesex and Rushville as datum, make the altitude of the valley plain at Potter about 900 feet. The lower and broader delta plateau is about 1080 feet, and the higher, summit plateau about 1150 feet. This higher level corresponds with the summit levels of the several old deltas in the Keuka Valley proper. The lower level represents some stage of the Flint Creek Valley waters not positively correlated at the time of this writing. As the waters fell in the Flint Creek Valley, the ancient stream, continually cutting down to the local base level, bisected and eroded the earlier delta deposits.

While not so extensive as some deposits of similar origin, this delta is a comparatively large one for the ephemeral glacial lakes of the region. By estimate it is about one-third of a mile across.

The form and topography of the delta and the included basin are fairly shown in the accompanying sketch. The dis-



Kettle in Delta at Potter, N. Y.

tances are by eye-estimate and the elevations by aneroid. While the absolute elevations are not exact, the relative heights are approximately accurate. The sketch does not show the rock cut nor the continuation of the two terrace levels along the ravine upon the north side, these being perhaps one-eighth of a mile north of the area shown in the map. The higher level is there a filling of an angle or recess in the hills, about 40 rods wide and with a bar or ridge on the front. The lower level is represented by a rock terrace about 10 rods wide. Behind the higher plateau, on both sides of the ravine, the ground is lower, with ridges and hollows transverse to the stream direction.

The materials composing the delta are quite variable and poorly assorted, containing an unusual amount of large stones and even boulders. This is epecially the case on the northeast side of the 1080 feet plateau, where several heavy stone fences have utilized only a portion of the field stone. These, however, might be wholly attributed to the powerful stream, but many larger and angular boulders on the slopes of the basin are not so explained.

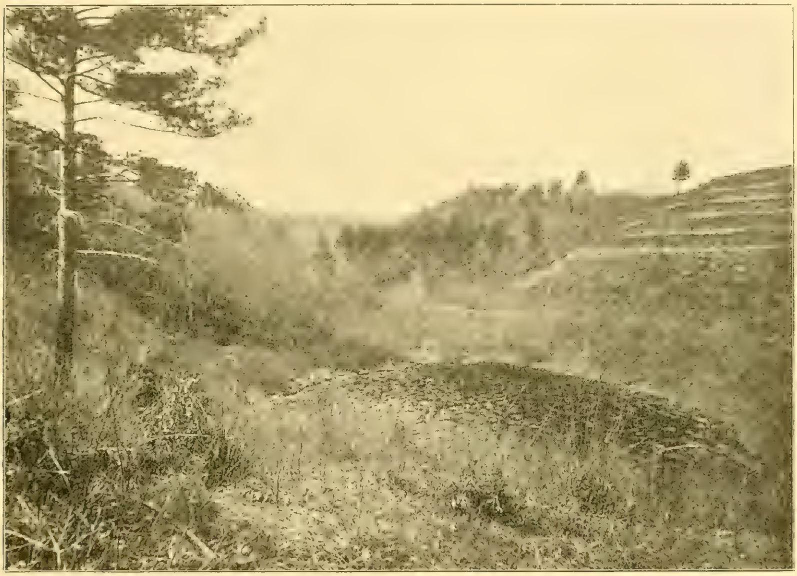
Of the origin of the kettle two hypotheses have been considered; one, that it was a result of capricious currents and deficient filling, the other that the basin is a portion of the space occupied by a block of ice during the deposition of the delta. The first explanation was suggested by the form of the spitlike, sloping ridges on either side of the swamp, the location of the deepest part of the basin at the extreme edge of the delta, and by the existence, in other deltas, of smaller kettles apparently produced by the aqueous forces alone. This explanation is now thought inadequate for the Potter basin.

During the study of this feature correspondence was held with Professor J. B. Woodworth, from whom valuable suggestions have been received. The sketch and photographs were sent to him, and he thought the Potter phenomena similar to other basins which he had studied in New England, and the genesis of which is confidently referred to ice-blocks. The writer accepts this theory for the origin of the Potter basin.

The deepest part of the basin is an oval swamp which holds water until removed, apparently, by evaporation. This indicates an impervious bottom. The depth of the vegetal accumulation is undetermined, but it seems probable that the original bottom of the kettle must have been in till or on rock, and below the water-laid drift. It seems improbable that such a deep hole, with walls so steep, could have been produced as a constructional feature in open water. If such were the case, the spitlike points inclosing the kettle should consist of the finest material brought down by the dying currents. The material, on the contrary, is not sand or even fine gravel, but stony gravel, and the

material of the low ridge at the notch opening into the basin is more like till than it is like gravel. Water movement probably had some part in the formation of the ridges, the currents sweeping about the half buried ice-block.

If the basin were due to deficient filling obviously the inner slopes should consist of finer material dropped by the weakened



Kettle in Delta at Potter, N. Y. View of deepest part looking north.

currents. Such is not the case. The materials are stony, and even large boulders occur. The writer observed no boulders which might not possibly have been rolled by powerful currents, although the much more reasonable explanation would attribute them to ice transportation. The owner of the larger part of the basin said that blocks of stone exist in the basin "as large as a team could haul."

The existence of elevated portions or isolated areas somewhat above the general plateau level might be regarded as due to erosion of the surrounding area, but seem more reasonably

due to contributory deposition by ice, especially as they are quite stony.

The ice-block was probably not entirely buried but projected above the surface of the delta, otherwise the deep swamp kettle would have been partially filled with the water-laid delta material falling in upon the melting ice. The notch at the edge of the kettle is apparently a constructional form, and there is no evidence of any current of water having flowed through it. It is still a narrow ridge, although somewhat flattened or lowered by use for a roadway leading into the basin. The water from the dissolving ice-block probably filtered out through the surrounding gravel.

A natural objection to the ice-block theory is the existence of such an isolated mass of ice for a great length of time. The relations of the stream and delta with the water bodies require the ice-front to be removed some uncertain distance to the northward. This objection, however, has not been given great weight by the students of similar phenomena.

This basin is by far the largest one that the writer has seen in the lacustrine deposits of western-central New York. However, it is not the only one suggesting ice-block genesis. Other deep steep-sided kettles have been seen in the deltas, especially on the slopes of Seneca and Keuka valleys, which may most reasonably be attributed to such origin. The writer has particularly in mind one a short distance above the Hector station, on the east side of Seneca Lake. This seems to lie above the plane of glacial waters and was apparently formed in the exposed delta.

In many deltas, small basins, or hollows, or bowls, occur which have been attributed to aqueous forces alone. These are usually located behind embankments or bars lying transverse to the stream, and vary in form from hollows open at one end to well enclosed kettles. So far as noted, although close study has not been made, the walls are of clear sand or gravel, the depths not great as compared with the breadth, and the forms are simple curves. Their origin seems explained by conflict of waves and

shore currents with the detritus-bearing stream currents. On the lakeward side they are usually bounded by a spit or bar formed transverse to the stream current. Some of the larger and more irregular depressions are bounded landward by the original surface of the valley border, but such are more likely to be open on the side away from the delta-forming stream.

Kettle in Delta at Potter, N. Y. General view; looking northwest from opposite side of Flint Creek Valley.

Those which are confidently referred to aqueous forces occur below the water plane, or are surely subaqueous.

Professor Chamberlin in discussing "kettles," in 1877, suggested four possible methods of origin: (1) Irregularities of deposition or heaping of the drift; (2) the pushing of one drift ridge unconformably against a preceding one; (3) the incorporation of ice-blocks; and (4) under-drainage. To this enumeration the writer would add a fifth method, (5) circum-deposition, by capricious stream currents in the face of wave action, or deficient filling on delta terraces.

The basins which occur in broad stream deposits, and which have suggested the name "pitted plains" have been confessedly difficult of explanation. The notable ones near New Haven have been thought to be due to deficient filling, or to whirling currents in the river. Professor Woodward informs the writer that he is convinced, from his personal examination, that these are of ice-block genesis. Such basins have not been often observed in New York. The best example that has fallen under the writer's observation lies near the village of Tully, upon the south, in the gravel plain left by the glacial waters. It borders the highway leading from the station and village to the Assembly grounds, and is of irregular shape and large extent. The most reasonable explanation is that it was the site of an isolated mass of ice, but whether buried in the gravel or projecting above is not determined, no study of the basin having been made. The occurrence further south, in the same detrital plain, of numerous lakelets, suggests that there are probably many similar basins in the locality.

SUMMARY.

The basins in deltas seem to be divisible into two classes:

(*a*) Those by ice-block origin, and

(*b*) Those by circumdeposition.

These may be discriminated by the following theoretical characters:

(*a*) Shape usually irregular; relatively deep; walls steep; material of the walls coarse or even till-like, with possible boulders; size, often large; position, often above the water-plane. (These characters would be greatly modified in cases where the ice-block was wholly buried in the drift.)

(*b*) Position always beneath water-plane, and usually behind a bar or embankment; depth relatively small; shape, with smooth curving outlines; material of the walls, well assorted and finer than the adjacent delta mass.

HERMAN L. FAIRCHILD.

A SYSTEMATIC SOURCE OF EVOLUTION OF PROVINCIAL FAUNAS.

The deformations of the outer portion of the solid part of the earth familiarly known as the "crust" are the result of an intricate combination of adventitious and systematic movements. The latter spring from the predominant action of the great stresses that affect the body of the earth; the former, from intercurrent variations in the expression of these dominant agencies due primarily to the rigidity of the earth, and secondarily to inequalities in its density, to changes in its internal temperature, and perhaps to other conditions. Were the earth a homogeneous liquid, the adventitious features would disappear and all its changes of form would be systematic, or if not absolutely all, at least all which seriously affect its deformation. While the adventitious movements that make for heterogeneity of configuration must be recognized, it is the function of the geologist to discriminate and emphasize the systematic factors and to relegate the adventitious elements to their proper subordination.

It is assumed that the fundamental movements which affect the earth's form are centripetal and that the dominant fact in the bodily history of the earth is the shrinkage of its outer parts, as has been so signally urged by Suess. Its upward movements may be regarded as adventitious, since they are incidents due to the restraint which rigidity puts upon a perfect adjustment to the demands of its contractile forces, or to variations from symmetry of substance or of temperature which only become effective through its rigidity. In a slightly different and broader sense, the continents may be said to be adventitious while the ocean basins may be said to be normal. We must hasten, however, to qualify this idea, for the ocean basins have obviously sunk beyond the normal level which the surface of the earth would assume, did not rigidity deform it. The uniform spher-

oidal surface to which an ideal earth would be adjusted lies about 9000 feet below the ocean surface.[1] The portions of the ocean basin below this normal level represent an excess of shrinkage. The continental masses which stand above this average level represent a deficiency in shrinkage. This average level is the natural datum plane from which the continents may be conceived to rise. The ideal upper surface of a continent may be said to be the sea level, a plane which the upper surface of the continent constantly approaches but never entirely reaches. That portion of it which is exposed above the sea level undergoes constant truncation by air and water. The portion beneath the sea level is being constantly built up by the deposition of land wash about its borders, forming a sea shelf whose summit plane is the sea level.[2] As a result of these activities, continued throughout the ages, the continents have come to be approximate platforms whose theoretical upper horizon is the sea level. To this they are accommodated more or less approximately, but never perfectly. They reach their most complete adjustment after long intervals of relative quiescence, when base-leveling attains its highest degree of perfection. They depart most widely from the theoretical surface at the climax of great periods of crustal readjustment to accumulated internal stresses. Such periods of greatest departure inaugurate periods of maximum activity, both on the part of the leveling forces, whose function it is to reduce the land surface again to the sea level, and on the part of the depositional agencies whose function it is to build up a sea-shelf around the borders of the continent. In other words, agencies for the replanation of the platform are put into maximum activity by the very agency which deformed it. If we conceive the continental platform to be the basal portion of a broad truncated pyramid whose bottom rests upon the ideal average level, 9000 feet below the sea surface, and whose truncated summit is ideally at the sea level, it

[1] GILBERT, Article "Earth," Johnson's Cyclopædia.

[2] See "The Ulterior Basis of Time Divisions and the Classification of Geologic History," JOUR. GEOL., Vol. VI, No. 5, 1898, pp. 449–462.

may be said that the widest departure of the average land surface from this ideal summit level has probably at no time exceeded 25 or 30 per cent. of the whole height of the platform, while at times of greatest approximation to the theoretical summit level through base leveling, its departure has probably not reached 10 per cent. of the whole height of the platform. The conception of a continent, therefore, as a platform maintained against deforming agencies by constant truncation of the protruding portions and by constant upbuilding about its borders is not seriously vitiated by the inequalities which crustal readjustments force upon it from time to time.

The ocean basins, considered as inverted plateaus or anti-plateaus, have no analagous agency for the reduction of their bottoms to an ideal plain, and their inequalities are greater (in their broad features, but not in detailed accentuation), and yet here is a reasonable approximation to a bottom plain, for more than half of the oceanic bottom lies between 12,000 and 18,000 feet below sea level. But the variation of 6000 feet included between these limits would be regarded as very large if it were a land surface.

More or less warping of the surface of the solid part of the earth is doubtless in progress at all times, but there is much concurrent geologic evidence to the effect that the really mportant changes are periodic rather than uniformly progressive. The most important items in this evidence are the great base levels and the great epochs of mountain making, the former pointing to long periods of relative quiescence, the latter to exceptional periods of disturbance. In the larger conceptions of the earth movements, the minor warpings may be ignored, but in the interpretation of the details of the earth's history they play a not unimportant part. The degree of importance of this part is dependent upon the critical relationships which the warping may bear to sea-level relations. The present study is concerned with such relationships in their bearing upon the progress of marine life.

The discussion proceeds upon the following general concep-

tions: (1) The continents are platforms whose summits are accommodated approximately to the sea level by truncation and by concurrent circumjacent filling. (2) The normal and the dominant feature of each readjustment of the outer part of the crust to internal contractional stresses is the sinking of the ocean basins and the enlargement of their capacity. (3) The incidental consequence of the sinking of the oceanic basins is the withdrawal into them of an increased amount of the epicontinental waters and the establishment of a new shore line upon the borders of the continent lying at a lower level than the preceding one. (4) The main readjustments are periodic and are separated by intervening stages of relative quiescence. (5) The continental platforms are subject to warping, partly due to the lateral thrust of segments of the earth as they sink (especially those segments that lie beneath the ocean), partly to internal changes of temperature and the intrusion of liquid matter, and partly to the settling of the continent when, by any of the preceding agencies it has been forced upward beyond the plane of isostatic equilibrium, the settling being accomplished through the slow quasi-fluid creep of the rock under gravitative stress.

As a mode of approach to the critical attitudes of sea and land which favor the evolution of provincial faunas, two more general and systematic attitudes which favor respectively general expansional evolution and general contractional evolution may be considered.[1]

1. *Conditions favorable to general expansional evolution of marine life.*— It is to be understood that only that element of marine life is here considered which has for its habitat the relatively shallow sea water adjacent to the land. Geologically speaking we know very little respecting the true abysmal life of the past, and only such little about the surface pelagic life as became incidentally involved in the terrigenous deposits. In considering the shallow-water life adjacent to the land we are, therefore, considering practically that phase of marine life which alone enters effectively into the geologic record. The conditions

[1] These were discussed on pp. 454–459 of preceding number of this JOURNAL.

favorable to an expansional evolution of this shallow-water marine life are those which ensued upon a protracted period of base leveling.[1] This, by its very terms, implies a protracted period of freedom from great movements on the part of the land or the sea. At the climax of such a period there is normally an extensive transgression of the sea upon the continental platform which assumes two phases: (1) the development of broad sea-shelves by the cutting back landward of the sea cliff and the building out seaward of the submarine sea terrace by means of the land detritus; (2) the creeping of the sea waters far inland upon the lower portions of the continent.

At first thought it may be questioned whether the land will not be *extended* by the addition of detritus to its border, and, still further, whether the transgression of the sea is genetically connected with base leveling and is its normal attendant. That the land is now being extended in certain places by detrital accretions to its borders, as in the case of deltas, is beyond question, but it is equally beyond question that the sea is advancing in other places, and it will probably be apparent, after a careful inspection of the continental coasts, that on the average the sea is advancing rather than retiring. But the present is far removed from a base-level period. The streams carry to the sea much more detritus than they would were the surface closely approaching a base level. The sea also, it is to be admitted, is better able to carry detritus back to deep water under present conditions than it would be if its sea-shelf were greatly extended. Conclusions drawn from present conditions are, therefore, embarrassed to this extent on both sides. The issue is really a contest between the ability of the streams to deliver detritus at the coast line and the ability of the sea to carry it back to deep water. The delivery of the streams is a declining factor which approaches zero as the base level is approached. The carrying ability of the sea is much more

[1] A suitable sinking of the land independent of base leveling may produce similar though not quite identical results, but in so far as this is adventitious it does not fall into the category under discussion here.

nearly constant. It is reduced, indeed, by the growing width of the sea-shelf. But the growth of the sea-shelf on its abysmal border must necessarily be slow because of the great depth to be filled, and hence, unless the shelf grows inland, its extension is relatively slight and the ability of the sea to dispose of the detritus borne into it remains nearly constant. With the inevitable decline in the delivery of land wash, as base level is approached, the disposing power of the sea must gain the ascendancy. It would seem to be almost obvious that if there were no movements of the crust for an indefinite period the ultimate result must be the complete truncation of the land to a level below the effective reach of the waves.

But the case does not rest simply with the results of the contest between the diminishing stream action and the nearly constant wave action. There are two supplementary factors which aid the latter. (1) The deposit of the detritus of the land in the sea raises its level. If the average elevation of the present land be taken at Lapparent's figures, 2120 feet, its truncation and removal to the ocean would lift the sea level 700 feet (making no allowance for the spread of the sea). This would certainly be effective in advancing the sea upon the land. (2) The continents after the relative upthrusts attendant upon crustal readjustment probably stand on the average above the plane of isostatic equilibrium, as indicated in the existing status by pendulum observations. From this they should settle back toward equilibrium by virtue of the quasi-fluency of the rocks. The effects of this might, perhaps, decline as erosion proceeded, but the shifting of the load to the borders of the continent would probably aid in depressing them and facilitating the advance of the sea.

The inland extensions of the sea attendant upon such an advance may be conveniently designated epicontinental seas. The great sea which lies between Europe and Africa is properly termed a mediterranean sea, since it really lies between the continents in a deep basin descending to depths of 6000 feet and more. But the seas here referred to as epicontinental are not

of this kind, but are such as are formed by the creeping out upon the low parts of the land of a film of the sea, as it were. The North and the Baltic seas, the Gulf of St. Lawrence and Hudson's Bay are adventitious examples.

It is obvious that at a stage when the sea-shelves and the epicontinental seas were thus extending themselves the conditions for the expansional evolution of shallow-water marine life were signally favorable. In so far as land detritus is inimical to such life, an additional favoring factor is found in the reduction of the surface relief and the consequent diminution of the land wash. The seas at such stages were being not only extended but progressively clarified. A further incident of such stages is the free intercommunication of the life. All of the great continents are at present connected by submerged portions of their platforms and appear to have been so united from the Cambrian times onward. Europe is connected with Greenland by a shallow tract, embracing Iceland, and Greenland, in turn, with the Arctic islands, and thence with the northeastern part of the American continent, constituting a northwest passage for European shallow-water life. On the other hand, Asia is connected by a tract underlying Behring Sea and Straits, and by a broad belt along the border of the Arctic Ocean of unknown width, constituting a northeastern passage for Eurasian life. At times of base leveling there are broad sea-shelves girdling all of the continents, as well as internal epicontinental seas affording other connections; so that altogether the facilities for the migration and the intercommingling of the faunas are exceptionally propitious.

At the same time, as I have endeavored to show in another article in this number,[1] the atmospheric and climatic conditions are uniform and favorable to the widest distribution of life.

In such a period, therefore, is to be found the climax of conditions favorable to expansional evolution and to the development of a world-wide fauna of a composite and comprehensive

[1] The Effects of Great Limestone-forming Epochs upon the Constitution of the Atmosphere, pp. 609.

type. Such faunas appear to characterize the Middle Silurian, the Middle Ordovician, the Carboniferous, and the Cretaceous periods, and in a less pronounced degree the Devonian, the Jurassic, and the early Tertiary.

(2) *Conditions imposing general restrictional evolution of marine life.*—If at the close of a period of great base leveling attended by expansional evolution of marine life, as just outlined, an epoch of profound readjustment to the earth's accumulated contractional stresses ensues, the great feature of which consists of the sinking of the ocean basins or some large part of them, the effect is to withdraw the waters from the surface of the continental platforms into the basins thus increased in capacity and to establish a new shore line somewhere near the edge of the continental platforms. If the enlargement of the capacities of the ocean basins is pronounced, a new shore line may be established, not upon the upper face of the continental platforms, but upon their abysmal slopes. In this case the shallow-water belt will be narrow and will consist of a rapidly shelving shore tract. It is obvious that the great expansional fauna which has occupied the broad sea-shelves and the extended epicontinental seas of the preceding period will be compelled to follow the retiring sea and crowd itself into this restricted zone on the abysmal slope of the continents. It is further obvious that, in addition to the restricted area into which the fauna is thus forced, the new conditions will be in many respects uncongenial, for the streams will be rejuvenated and the amount of land wash will be greatly increased. Those species whose existence is dependent upon clear seas will be in imminent danger of extinction. Certain species to which these conditions are congenial may on the other hand be favored, but the grand result must necessarily be the destruction of the larger part of the previous expansional fauna and the forced adaptation of the remainder to new, and on the whole sterile and hostile conditions. A stage of general repressional evolution is thereby inaugurated and, in a comparatively short period, it is safe to assume, all or nearly all preceding species will have passed out of existence and new species,

in a much more limited number but better adapted to the new conditions, will have been introduced. Such restrictive conditions appear to have been prevalent in a pronounced degree at the close of the Palæozoic era and less notably at the close of the Ordovician period and at other times. But in neither of these cases were the repressional conditions complete, and it is improbable that the ideal conditions of repression here sketched were ever fully realized.

(3) *Conditions favorable to the evolution of provincial faunas.*—It is obvious that if the sea shore be drawn far down the abysmal slope of the ideal sea-shelf, moderate warpings of the continental platform will have little or no effect upon the conditions of faunal development, for whether the shore stands high or low upon this abysmal face the shallow-water tract will remain a mere ribbon. But if, on the other hand, the sea be withdrawn merely to the angle of the sea-shelf the relations between sea and land will be critical and every warping of the surface platform will be decisive either in emphasizing the restrictional influence or in relieving it. To illustrate by a specific case: suppose the sea level to lie accurately at the angle of the ideal sea-shelf, and that portions of the continental platform are warped upward to the amount of 500 feet, while alternating portions are warped downward to an equal amount. The shore line in the former case will lie along the abysmal face and the shallow-water tract will be narrow. In the latter case the shore line will be thrown out upon the upper surface of the sea-shelf and the shallow-water tract will be relatively wide. If the sea-shelf be ideal its upper surface will have a very gentle slope and the downward warping of 500 feet would carry the shore line well inland and give a notable embayment favorable to the perpetration and development of shallow-water life. Under such conditions of alternate warping up and down the continental platform would be bordered by embayments favorable to life, separated by narrow shore tracts which would be largely prohibitive of free migration of shallow-water life between the embayments. Each embayment will there-

fore develop its fauna in measurable independence. Each embayment will become the generating area of a provincial fauna. If now a period of quiescence ensues and systematic continental evolution proceeds, these embayments will become extended landward and grow into extensive epicontinental gulfs and perhaps at length into broad epicontinental seas, and their faunas will expand accordingly. In the progress of this development they may come into conjunction with each other and a commingling and conflict of faunas ensue, resulting in the evolution of a new assemblage of life of a composite type.

Whether the internal progression reaches this stage or not, the development of the sea-shelves must at length attain a stage such that coastal migration will become free and the faunas of the embayments become commingled by coastwise extension. The ideal result of this line of progression is the evolution at length of a general fauna of the expansional type and the concurrent elimination or fusion of the provincial features, for the line of progress is essentially expansional, and the result is expansional evolution. It differs only from an expansional evolution starting from a general restrictional evolution in the commingling and conflict of well-differentiated faunas resulting from provincial development.

At the close of the Silurian period the sea appears to have been drawn away from the land into the critical attitude here indicated, and the basin of the St. Lawrence Gulf and probably that of Hudson's Bay and perhaps other embayments on the borders of the continent, appear to have furnished refuges for the retiring fauna of the Silurian period, and to have become areas in which the origination of provincial faunas took place. The consecutive series of sediments of the St. Lawrence embayment, though not yet perfectly investigated, give good grounds for the belief that the transition of the Silurian fauna into the Helderberg fauna took place there. After its provincial character had been fully assumed and the re-advance of the sea opened the way into the interior through the Champlain tract, it reinvaded the interior basin and left its record as a distinctive

fauna. It was followed in succession by the invasion of the Oriskany fauna, whose place of origin is less clear, but which followed the Helderberg track; by the Corniferous fauna, apparently from the Hudson's Bay embayment; by the early Hamilton fauna, apparently from some southern embayment; and by the later Hamilton fauna, apparently from the Mackenzie embayment, or beyond, thus giving to the Devonian period a distinctive aspect as a time of successive invasions of provincial faunas generated in embayments about the borders of the continent.[1] Had the waters been withdrawn so far as to have emptied these embayments, as was apparently the case at the close of the Palæozoic era, a general repressional evolution would have taken the place of this pronounced provincial evolution. The determinative element, therefore, seems to have been *the critical attitude of the sea to the land* which gave maximum effect to the inequalities of its border.

It is obvious that any previous warping of the continental platform by which a portion of it is submerged may give rise to an embayment covered by relatively shallow water at times of the ocean's withdrawal, and that this may become a refuge for the retreating faunas, and may break the force of the general repressional evolution which would otherwise ensue. This may take place even when the seas are withdrawn down to a level much below the critical horizon just discussed. Such embayments may be regarded as adventitious, since they are not the product of the systematic actions here discussed. But such adventitious embayments were probably always present at times of great withdrawals of the sea, and so broke the force of repressional evolution. In the withdrawal of the sea at the close of the Palæozoic era, the Mediterranean basin appears to have afforded such a retreat for the hard-pressed Permian life of the western part of the Eurasian continent, and to have become a transitional tract in which originated one of the three or four great provincial faunas that advanced upon the land in the Triassic and Jurassic periods. A similar great embayment appears to have existed in

[1] Drawn mainly from the studies of H. S. Williams and Stuart Weller.

the upper Indus and Ganges basins, involving the site of the present Himalayas, and this appears to have been preëminently a transition tract from the Palæozoic to the Mesozoic eras.[1] The adventitious factor in such cases becomes a saving clause so far as the efficient preservation of remnants of the previous fauna is concerned. But even the adventitious factors receive their importance from their critical relations to the systematic attitudes of land and sea upon which chiefly depend the great lines of progress of marine life.

T. C. CHAMBERLIN.

[1] GRIESBACH, Mem. Geol. Surv. India, Vol. XVIII, pp. 1–232, 1891.

THE INFLUENCE OF GREAT EPOCHS OF LIMESTONE FORMATION UPON THE CONSTITUTION OF THE ATMOSPHERE.

THE virtues of carbon dioxide are in inverse ratio to the sinister reputation which "a little knowledge" and a narrow homocentric point of view have given it. As a constituent of the atmosphere it is as necessary to the maintenance of life as oxygen because it is the food of plants and they in turn are the food of animals. Its peculiar competency to retain the heat of the sun renders it a decisive factor in the maintenance of that measurable constancy and geniality of temperature upon which the existence of life depends. It is a leading agency in the disintegration of crystalline rock and is a necessary factor in other geologic changes. It is an essential link in a chain of vital processes which involve all the constituents of the atmos phere. Inherently it may be no more necessary to these processes, save in its thermal nature, than is oxygen, but being the *minimum* factor in the atmosphere it becomes regulative and decisive, because variations in it affect the whole cycle of processes dependent on it, while similar variations in the major constituents may have no appreciable effect. It is the *least* chemical constituent of a mixture that determines the amount of reaction. A loss of nitrogen or oxygen equal to .0003 of the atmosphere would doubtless be wholly inconsequential, while that amount of loss of carbon dioxide would be fatal to life and to many important geologic processes. Oxygen would doubtless become the critical factor if geologic processes in the aggregate consumed it more rapidly than they do carbonic acid. But the reverse seems to be the case now, and it has quite certainly been the case throughout the determinable portion of geologic history. This becomes equally apparent whether we approach the question in the order of the actual processes or the reverse.

Taking the average constitution of the crystalline rocks as a basis, even a rude inspection shows that the consumption of carbon dioxide involved in their decomposition far surpasses the consumption of oxygen.[1] Or, reversing the mode, an estimate of the amounts of carbon dioxide and of oxygen respectively, which would be freed from the sedimentary deposits of the earth if they were again reduced to the condition of silicates analogous to their primitive state shows a like excess of carbon dioxide. From these considerations, which do not need to be given numerical expression, it will be apparent that carbon dioxide has suffered much more consumption in the progress of the geologic ages than has oxygen. That its consumption has surpassed that of nitrogen is too obvious to require argument.

Whatever the original quantitative relations of the atmospheric constituents, the effect of geologic processes has been their reduction to a quantitative order which is inverse to their functional activity. There is hence a preponderance of the inert and relatively non-participant nitrogen, a medium amount of the more active oxygen, and a minimum amount of the most participant element, carbon dioxide.

Now as the activities of the atmospheric constituents are in many respects connected with each other and mutually dependent, it is obvious that the factor which is at once minimum in quantity and maximum in participation must necessarily be the critical factor of the atmosphere. It is not too much to say that the whole order of vital procedure is hung preëminently upon the function of carbon dioxide as the decisive factor, and it is scarcely too much to say the same of many of the most important of inorganic processes.

The chief reservoir of available carbon dioxide on the sur-

[1] The amount of carbon dioxide which crystalline rocks hold in their microscopic cavities, recently shown by Tilden to be considerable, is only a small fraction of what is required for the carbonation of the rock containing it, on the average. We cannot look to this as a source of enrichment of the atmosphere so far as the superficial rocks which undergo chemical decomposition are concerned, though it may be an important source of enrichment when freed from the deeper rocks by the processes of vulcanism and by other means.

face of the earth is not, however, the atmosphere but the ocean. Reservoir in the ulterior sense is not meant, but in the immediately available sense. I entertain the hypothesis that the interior of the earth is the chief terrestrial reservoir of carbon dioxide in the ulterior sense, and that it is a leading source of secular supply. If Tilden's recent analyses of the carbon dioxide stored in the microscopic pores of rocks, or otherwise occluded within them, be representative of the whole interior of the earth, the total mass of carbon dioxide stored within is something prodigious.[1] To how great an extent this is given forth from age to age and becomes a source of atmospheric supply cannot be determined from present data, but I am fully persuaded that the subject is one of the most vital which now invites investigation. The possible feeding of the atmosphere from cosmic sources also invites definite inquiry. But these are ulterior sources of supply of a secular nature and lie apart from the immediate question here discussed. This incidental mention may serve to definitely set them aside and to forestall misunderstanding.

For the purposes of this paper it is assumed that the constituents of the atmosphere and of the ocean have been essentially the same as at present, and no ulterior source of supply or of loss is taken into account. The endeavor here is merely to trace the effects of a great epoch of limestone formation upon such an atmosphere as we now have, attended by an ocean similar to the present one, and with land relations such as accompany great limestone-forming epochs and their antitheses.

A computation of the approximate amount of available carbon dioxide in the present ocean, based upon the observations of the Challenger Expedition as elaborated by Dittmar, shows a content of about eighteen times that contained in the present atmosphere. This embraces only the carbon dioxide held in the two states familiarly known as "free" and "loose;" that is, (1) carbon dioxide which is simply held in solution, and

[1] On the Gases enclosed in Crystalline Rocks and Minerals. By W. A. Tilden. Chemical News, April 9, 1897.

(2) that which constitutes the second equivalent of the bicarbonates — essentially the bicarbonate of lime. The estimate does not include the carbon dioxide which is united with the basic oxides to form monocarbonates and which may be said to be fixed. To put the matter in another form, only that carbon dioxide enters into the computation which separates from the sea water upon evaporation.

According to the old method of interpreting analyses the carbonate of lime present in sea water should all be bicarbonate. It appears, however, from Dittmar's investigations that the amount of "loose" carbon dioxide in the ocean is only about one-half what would be required if all the carbonate of lime (interpreted under the old system) were bicarbonate. The proportions are about as though the lime existed in the state of a sesquicarbonate — a compound of doubtful existence. Under modern methods of interpretation this lower proportion is theoretically explicable, for each of the basic oxides in the sea water enters transiently into combination with each of the acids, and a larger proportion of monocarbonates is thus consistent with solubility, and, in addition, free ions of both oxides and acids are concurrently present. Under this system of interpretation the proportion of carbon dioxide necessary to maintain the lime in a state of solution is reduced. In accordance with these direct determinations it will be assumed in the discussion that the "loose" equivalent of carbon dioxide is only half the amount necessary to render the carbonate of lime a bicarbonate. It is by no means certain that under the conditions of an atmosphere rich in carbon dioxide the amount would not reach the full second equivalent required by the old chemical philosophy, but the more conservative basis serves equally well the purposes of this discussion.[1]

Data are lacking for more than a very rude approximation to the amount of free carbon dioxide held in simple solution in the ocean, but such data as are available seem to indicate that it

[1] The elaborate investigations of Treadwell and Renter (Zeitsch. Anorg. XVII, p. 170) indicate that the lime is essentially bicarbonate so far as it is carbonate at all.

probably does not exceed two or three times the amount held in the atmosphere. If we assume these figures to be approximately correct there remains, in a semi-fixed or loose condition, carbon dioxide to the amount of fifteen or sixteen times the present normal content of the atmosphere. This large reserve of carbon dioxide is the radical factor in this discussion.

Let a status of land and water and of atmosphere and ocean, such as now exist, be assumed. Since a certain amount of carbon dioxide is associated with the monocarbonate of lime in solution as the second or bicarbonating equivalent, and since the secretion and deposition of the lime takes place as the monocarbonate, the associated carbon dioxide is set free. The deposition of limestone is, therefore, a process of conversion of semi-fixed carbon dioxide into free carbon dioxide. This free carbon dioxide under the law of diffusion distributes itself through the ocean and the atmosphere according to the demands of tensional equilibrium. The ocean and the atmosphere are thereby alike enriched in carbonic acid. If this process were continued without reciprocal action of the opposite kind, the ocean would in time be exhausted of its calcium bicarbonate and the semi-fixed factor would all become free.

But as elsewhere urged[1] the disintegration of crystalline rock through the agency of the atmosphere consumes carbon dioxide in the carbonation of the alkalis and alkaline earths contained in them.[2] In particular, the calcium silicates of the crystalline rocks become calcium bicarbonate and are in part carried in solution down to the ocean. Over against the liberating function of lime-deposition, therefore, there is set this reciprocal process of fixation. Over against the enrichment of the atmosphere in carbon dioxide due to the former there is a depletion due to the latter. Now if these two processes were in perfect balance, a static condition of the atmosphere, so far as these factors are concerned, would be maintained. It is, however,

[1] A Group of Hypotheses Bearing on Climatic Changes, JOUR. GEOL., Vol. V, No. 7, October–November, 1897.

[2] The organic cycle and other processes affect the supply and loss of carbonic acid concurrently, but they are purposely omitted here for simplicity's sake.

beyond reason and beyond geological evidence to suppose that these are habitually in perfect or even in approximate balance, for at certain stages the exposure of the land has been large and its elevation high and the process of rock disintegration and carbonation has been notably favored. Coincident with this the ocean has at such times been extensively withdrawn from the continental platforms and the previous expanse of lime-depositing areas thereby greatly circumscribed. In addition to this, the rejuvenation of the streams has at such times brought into the ocean exceptional amounts of detritus and rendered the coasts uncongenial to many of the limestone-forming organisms. It is probable also that even the pelagic calcareous organisms have been at such times adversely affected directly or indirectly by these conditions. On the other hand there have been times when the sea crept out over great areas of the continental platforms and afforded vast expanses of shallow water congenial to the maintenance of lime-depositing life. There is direct palæontological and physical evidence that such extensive epicontinental seas were spread upon the eastern and western continents at the same time, as for example, in the Ordovician, the Silurian, the Carboniferous, and the Cretaceous periods. Geological evidence compels us likewise to recognize recurrent fluctuations in the prevalence of such limestone deposition, intermittent with the antithetical process of land degradation.

Returning now to our selected case based on the present status of atmosphere, ocean, land, and water, we may safely assume that one or the other of the two alternatives, the fixation of carbon dioxide, or the freeing of carbon dioxide, is at present preponderant. Either the carbonic consumption upon the land is in excess of the carbonic freeing in the ocean, or the reverse is the case; if not so momentarily, at least so habitually.

Let us assume, in accordance with the probable fact, that the disintegration of the silicates is now exhausting the carbonic acid of the atmosphere faster than the deposition of limestone eliminates it, and that, therefore, the calcium bicarbonate in the ocean is increasing. The result of this process if prolonged

without interference would be the exhaustion of the carbonic acid of the atmosphere, and, incidentally, the lowering of the surface temperature through the withdrawal of the heat-conserving influence of the carbon dioxide, the reduction of the moisture of the atmosphere through the decline of the temperature, the checking of the vegetal growth, and if the process were to proceed to its extreme, the destruction of vegetal life, and of animal life as well. There would also be concurrent diminution of the chemical disintegration of the rock because of the lessened supply of the disintegrating agency, carbon dioxide, and because of the reduction of the auxiliary agencies, warmth, moisture and vegetation. Theoretically, rock disaggregation by physical agencies might grow into relative preponderance over chemical disintegration, since it would be aided by the sharp oscillations of temperature which would follow the withdrawal of the equalizing blanket of carbon dioxide and aqueous vapor. In such a case the land detritus from crystalline areas would constitute arkose deposits which stand in genetic contradistinction to the limestones, mudstones, and sandstones, which are the result of chemical disintegration through the preponderant agencies of carbonic acid and water. Whether this is really the explanation of the arkose deposits that occur at certain geological horizons is not here seriously considered. The assumed procedure is simply carried to its logical extreme. Arkose deposits may certainly be made locally under present conditions.

But the process cannot reasonably be supposed, under current conditions, to go to the ultimate extreme of destroying all life and subjecting the nude surface to mechanical disaggregation ; for the process is self-checking. With the reduction of the carbon dioxide in the air, the rate of consumption is decreased as just indicated. At the same time the ocean is being enriched by the calcium bicarbonate carried down by the land waters, and the conditions there rendered more favorable for the formation of limestone and, through it, for the freeing of the second equivalent of carbonic acid. Even if the rate of freeing this

carbonic acid were reduced temporarily by the indirect adverse influences springing from the impoverishment of the life on the land, the continued reduction of the rate of consumption of carbonic acid on the land must cause it at length to fall below the freeing action in the sea, and the impoverishment of the atmosphere give place to enrichment which would run its course until the preponderance of action was again reversed.

But another element of vital importance enters the problem, the changing attitude of the land and the sea. Such changes may be systematic or adventitious. If they are adventitious the results are beyond easy discussion, but adventitious changes are believed to be subordinate to the systematic changes, since these latter follow (1) from coördinate movements of the earth's crust; (2) from uncoördinate movements of the crust which the ocean coördinates by its leveling function, and (3) from no movements at all. The last is the simplest and most representative case.

Let there be no essential movement of the crust for a prolonged period. That this has been an actual case repeatedly, the base levels of different periods testify. During such a period the height and the area of the land are both diminished. The rate of disintegration of the rocks is consequently reduced, and, concurrently, the rate of impoverishment of the atmosphere in respect to carbonic acid and of the conveyance of calcium bicarbonate to the ocean[1] is also diminished. At the same time the edge of the sea is advancing upon the borders of the land, partly by erosion, partly by the lifting of the sea level by the reception of sediments, and partly, perhaps, by the quasi-fluent creep of the continent toward isostatic equilibrium.[2] This results in the extension of the sea shelf and possibly in the formation of interior epicontinental seas, as exemplified notably in the central epochs of the Ordovician, Silurian, Devonian, Carboniferous, and Cretaceous periods. This extended sea shelf and these epi-

[1] The Ulterior Basis for the Classification of Geologic Time Divisions. JOUR. GEOL., Vol. VI, No. 5, 1898.

[2] Loc. cit.

continental seas furnish conditions congenial to the chief lime-secreting organisms. Preëminently is this true when approximate base leveling attends the wide transgression of the sea, as it normally does, since the two conditions are cogenetic. At such times the waters are relatively free from land wash, and the extended shelves and the epicontinental seas have their greatest availabilities of depth. These are the conditions theoretically most favorable to limestone formation. These seem to be the conditions that actually prevailed at the epochs of great limestone deposition. At such periods great quantities of carbonic acid previously stored in the calcium bicarbonate of the ocean were set free and the atmosphere enriched in carbon dioxide. It was precisely during such periods of special enrichment that the land was most incompetent to impoverish the atmosphere, because it was then smallest and lowest. During the prevalence of these conditions it seems inevitable that the enrichment of the atmosphere should have become notable. A rude computation may give some impression of the quantitative competency of a great deposition of limestone to set carbonic acid free. The limestones of the mid-Ordovician period may be taken as an example. According to the estimate of Dr. Tillo,[1] 17 per cent. of the land is covered by the Palæozoic series and 80 per cent. by the total sedimentary series. Taking no account of the loss by erosion, nor of the portions concealed by the ocean, and making the very conservative assumption that only one-fourth of the sedimentary area is underlain by this wide-spreading formation, and the further excessively conservative assumption that the Ordovician limestones average only fifty feet exclusive of impurities, and that only a half equivalent of carbon dioxide was freed for every equivalent of calcium carbonate extracted from the sea water, we still find the amount of carbon dioxide set free to be sixty times the present carbon dioxide of the atmosphere. It is obvious that this amount could not be extracted from an ocean like the present one without concurrent supply, for it is about four times as great as the ocean's avail-

[1] BERGHAUS' Physical Atlas. Introduction to Geological Maps.

able content. It seems apparent that a process which sets free carbon dioxide in so large a proportion to the total atmospheric content would be competent to vary that content notably, if, as contended, the process is subject to notable variations, and especially if, as also contended, the reciprocating process of fixation varies coincidentally with it so that the two mutually intensify each other's effects.

Dr. Arrhenius[1] has estimated that the addition of two or three times the present amount of carbonic acid to the atmosphere would give the genial climate in the arctic regions which the Tertiary flora indicates. Even if this estimate should be much too small, it would not seem to be beyond the competency of a great limestone-making epoch to enrich the atmosphere in carbonic acid sufficiently to thermally blanket the earth effectively and to so retain, distribute, and equalize the temperature as to render all latitudes available to vegetal and animal life. The notable feature connected with the extension of life to the high latitudes is the marvelous equalization of temperature. White and Schuchert[2] have recently given great emphasis to this by showing that in the Potomac epoch an almost identical flora flourished in north Greenland and in Virginia. A simple increase of solar heat, distributed as it is today, does not meet the demands of the problem. An equalizing and distributing factor seems to be indicated. And this, eminent physicists from Tyndall to Arrhenius encourage us to believe may be found in a change of the atmospheric constitution in the critical item of carbon dioxide, a change of no excessive amount and without serious variation in other constituents, except as they follow from this incidentally.

If the freeing of carbonic acid incident to limestone deposition were a potential factor in the equalization and amelioration of climate which permitted the extension of warm-temperate life to high latitudes, such extension should be coincident with the great limestone-forming epochs. Such appears to be the

[1] Phil. Mag., S. 5. Vol. XLI, No. 251, April 1896, pp. 237–279.

[2] Bull. Geol. Soc. Am., Vol. IX, pp. 343–368.

testimony of geological history. It was in the Middle Ordovician, the Middle Silurian, the Middle Carboniferous, the Middle Cretaceous and the early Tertiary that life of the warm temperate types prevailed in the arctic lands. And these seem to be periods of base leveling and of wide incursions of lime-depositing seas. It cannot at present be asserted, on the other hand, that there were intervening periods when warm temperate life did not prevail there, and could not because of low temperature. In the very nature of the hypothesis here entertained, such periods would be coincident with relative land elevation, and their record would be absent, or so obscurely indicated that only critical investigation directed to the point could detect it.

But in the lower latitudes we find evidence of aridity and of cold temperatures intervening between at least some of the periods of extensive limestone formation, as, for example, the saline deposits which took place between the great limestone-forming epoch of the mid-Silurian period and the similar epoch of the Devonian ; or, again, the saline and gypsum deposits and red sediments of the Permian and Triassic age between the limestone epoch of the Carboniferous and that of the Jurassic. In this gap also falls perhaps the glaciation of India, Australia, and South Africa. The Pleistocene glaciation and the measurable aridity of recent times, falling between the limestone-forming epoch of the early Tertiary and a possible limestone-forming epoch of the future which should theoretically follow upon the degradation of the continents, if crust movements remain in abeyance, may form another example.

In considering the antithetical epochs where limestone formation is at a minimum, and rock disintegration is at a maximum, it may be noted that at the close of the lime-depositing epoch the ocean is low in calcium bicarbonate and rich in carbonic acid, and is not then predisposed to deposit lime chemically, but is, on the other hand, in a condition to receive and hold the calcium bicarbonate sent down from the land. When, therefore, an epoch of special earth shrinkage and of readjustment to accumulated stress ensues, and the ocean is more fully drawn into the

deepened basins and the land exposed and incidentally corrugated, the conditions for the reversal of the atmospheric change are propitious.

If a computation be made of the amount of carbon dioxide that would be required to disintegrate the crystalline rock requisite to supply the clastic material for a great epoch of sandstone and shale deposition (allowing duly for old clastics used over), a competency to exhaust many atmospheric equivalents of carbonic acid will be shown. This, being correlated with limited limestone formation, and consequent scant returns of carbonic acid from the ocean, seems competent on its side to notably change the constitution of the atmosphere in the direction of poverty of carbonic acid.

The effect of the limestone-depositing epochs upon the atmospheric oxygen and nitrogen has been ignored for simplicity. While doubtless important, the process does not seem to have any such potential consequences as those which attend the decisive and regulative factor carbon dioxide. Its discussion will therefore not be undertaken here.

The action of intercurrent agencies has been purposely ignored. Some of these are quite obvious. The organic cycle of carbonic acid consumption and oxygen liberation by plants, and of carbonic acid production and oxygen consumption by animals, and the coördinate fixation and freeing of nitrogen alternately, was an ever present factor, and contributed in its own way to a constitutional change of the atmosphere. Although the cycle is measurably self-supporting, it is not a solution of the problem of perpetual motion, and the total result for a protracted period is a permanent alteration of the ratios and of the absolute amounts of the constituents of the atmosphere. But the discussion of this is reserved.

The periodicity of epochs of great limestone-formation reciprocating with epochs of great land extension has been assumed on the basis of a recent discussion.[1] That there were intervening

[1] The Ulterior Basis of Time Divisions and the Classification of Geological History. This magazine, previous number, pp. 449–462.

epochs when neither the one nor the other were greatly preponderant is not only not questioned, but will, in a separate article, be urged as the special agency of an important function in biological, as well as geological, progress.

Other limitations will suggest themselves, as the change of calcium carbonate into calcium sulphate, and the reverse, in the sea or in the course of organic processes, but it is believed that none of them radically affect the particular function herein assigned to great epochs of limestone formation.

T. C. CHAMBERLIN.

Studies for Students.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

III. REPTILIA.—(*Continued.*)

THERIODONTA.—This name is applied to what must be considered as a very unstable order of the reptilia. Composed as it is of the least well understood of the reptilian forms, it may at any time fall asunder under the light of new discoveries and be seen to be composed of several well defined orders instead of being a single one. The animals making up the order were originally placed by Owen in his *Anomodontia*, in the family *Cynodontia*, but were soon taken out and placed in a separate order, the *Theriodonta*. Owen's classification was arranged on the forms from South Africa only, and it was soon found that it would not suit the forms from America and Russia. Many schemes have been proposed to accommodate all of the different groups, but none has been arranged as yet that is at all satisfactory; there seems to be a general recognition of three distinct groups, but the value of these is a matter of much dispute. Lydekker, in his catalogue of the reptiles of the British Museum, would call the *Theriodonta* a suborder of the order *Anomodontia*, while Seeley, of the same institution and on the evidence of the same material, raises many forms that Lydekker regarded as families into separate and distinct orders. A quite common opinion among palæontologists, and one that may be of the greatest service to the student, is to regard the *Theriodonta* as an order and the three separate groups as suborders—the *Pelycosauria*, the *Cynodontia*, and the *Gomphodontia*.

The first of these the *Pelycosauria*, is represented most largely in the Permian deposits of the United States, but a few isolated

specimens have been found in the same horizon in Bohemia. They were in some respects of the most primitive type; the skull retained the two post-orbital arches, the teeth were simple in structure and without tubercles or basal band; the vertebræ were deeply bi-concave and pierced for the passage of the notochord; intercentra were present, and the sacrum was formed of two or three vertebræ. Not only were they the most primitive members of their order, but they were among the earliest of the land-living vertebrates after the *Amphibia*, and it is very interesting to note among their characters certain features that clearly foreshadow the culminating point of the order, the mammalia. Such characters are the great flattening of the quadrate bone and the partial surrounding of this element by the temporal bones of the skull, and the beginning of a differentiation of the teeth into specialized regions.

Dimetrodon, from the Permian of Texas, is the best known member of the suborder. There were two post-temporal arches, and the bones of the temporal region were all separate. The eyes were very large, almost perfectly round, and placed far back in the skull. The skull itself was abruptly terminated behind, and extended forward as a strong and rather high nose. The upper jaw was slightly convex on the alveolar border, and was armed with many strong, conical teeth that curved slightly to the rear; there were about three incisors in the jaw, the posterior or outer one being much larger than the others. Behind these came a considerable interval, marked by a deep notch at the junction of the premaxillaries and the maxillaries. Posterior to this came one or two very large teeth in the position of canines, followed by a long series of small conical, slightly recurved teeth of nearly equal size. The alveolar border of the lower jaw was concave to correspond to the curve of the upper, and there were two or three large teeth corresponding in position to the canines of the upper jaw. The surface of the palate and the pterygoid bones were covered by rows of small teeth. The quadrate was much depressed, and only appeared for a very small space on the side of the skull, being nearly covered by the adjoining bones. The

lower surface of the quadrate shows two parallel notches that accommodated a double condyle on the lower jaw. This absolutely prevented any lateral movement of the jaws in mastication. Not the least peculiar thing about the animal was the enormous extension of the neural processes of the spine; these were long and slender, becoming nearly as thin as a whiplash at the upper extremity. They sometimes reached a length of nearly three feet, as much as twenty-eight times the greatest diameter of the supporting vertebra. The limbs were short and stout, but from the location of the articular surfaces it seems that the legs were permanently bent, and that the animal could not raise itself from the ground. It is probable that it dragged itself along after the manner of the crocodiles. It is difficult to say what the appearance of the animal may have been. It is pretty certain that the immensely tall spines were clothed with at least a thin covering of muscle and skin, and then there would have been simply a tall dorsal fin that extended the whole length of the body. The tail of the animal was long, and the feet were strong and provided with claws. The whole brute could not have been less than eight or nine feet long.

Clepsydrops is a much smaller genus, known from the Permian of eastern Illinois and Texas. In general features it does not differ from *Dimetrodon* as far as the skeleton is known. It did not exceed a length of two or three feet.

Naosaurus can be told from *Dimetrodon* by the fact that the spines are not only elevated far above the bodies of the vertebræ, but are supplied with cross-bars like the spars of a full-rigged ship. The spines are larger and heavier than in either of the preceding genera, and are marked with shallow grooves that indicate the position of blood vessels, showing that they were covered with a layer of muscle of some thickness. Besides its occurrence in the Permian (Wichita division) beds of Texas, this genus is known from the Permian (Gaskohle) of Bohemia. The specimens from the latter locality indicate a smaller form, about two or three feet long, while the Texas specimens belong to animals nearly or quite as large as *Dimetrodon*.

The habits of these animals are a matter of great doubt. That they were very pugnacious, is well shown by the frequent fractures in the long and slender spines, which must have suffered severely when the animal got into a fight. They were carnivorous in diet.

From the Permian rocks of Russia come some very imperfectly known forms that seem to belong to this group. These are the fragmentary remains of animals discovered for the most part in working the copper mines on the west flank of the Ural Mountains in the provinces of Kasan and Orenburg in the old government of Perm. The remains are almost entirely from the upper layers of the Permian. They did not have the greatly elongated dorsal spines of the American and Bohemian forms.

Brithopus. — This form was described by Kutorga as early as 1838 from the province of Kasan, from what he then called the Keupfersandstein, now known to be upper Permian. The specimen consists of an imperfect humerus, showing the characters of the *Pelycosauria* and the African forms.

Rhophalodon is from the same region in Russia. It is characterized by the same features of the limb bones as the former genus, but the skull is unusually short and of great vertical extent; so great, indeed, as to give to it an absurdly square outline from the side view. The teeth are much stronger and stouter than those of the American forms, and have a tendency to develop in the lateral direction, giving them a rather broad outline and an appearance very similar to that of the American *Pareiasauria*, the *Diadectidæ*.

Deuterosaurus, from the province of Orenburg, in the same part of Russia, is even more similar to the American forms than the *Rhophalodon*; the skull is almost identical in appearance with that of the genus *Dimetrodon*. It seems strange at first sight to find these closely related forms from such widely separated regions as the United States, Bohemia, and Russia; but if we reflect for a moment that despite the great specialization of the American forms in the dorsal spines, this group is the most

primitive of the land-living reptiles, we may find a reason for the widespread distribution of the group.

The *Cynodontia.* — Under this head is grouped the majority of the South African forms, all except those that by their skull structure approach very nearly to the *Mammalia.* The forms considered here are the ones placed in the families *Galesauridæ* and the *Tapinocephalidæ* by Lydekker, in the catalogue of the fossil reptiles of the British Museum, under the suborder of *Theriodonta.* The group at first glimpse seems very like the *Pelycosauria*, but there is one very important distinction. The two postorbital arches of the first group have disappeared and are replaced by a single one that is either made up of the union of the two primitive ones, or is the single one left after one of them has disappeared; in all probability the first of these cases is the true one. The teeth are of carnivorous type, recurved, and in many cases differentiated into incisors, canines, and molars.

These forms are exclusively from the Karroo formation of South Africa. The position of this formation is not definitely known. It is either Permian or Permo-Triassic. If the evidence of the vertebrate remains is to be taken, it should be placed as far up in the geological time scale as possible, for there are found in these beds remains that are very closely related to forms that are found in the Lower Cretaceous of the United States.

Galesaurus, known from the skull only, was a small, lizardlike animal; the skull was depressed, with a rather long muzzle and very large temporal vacuities. The teeth were differentiated into the incisors, canines, and cheek teeth. The cheek teeth were furnished with small lateral cusps at the base. The whole skull was nearly four inches long.

Aleurosaurus is also known only from the skull. The muzzle is long but quite high, resembling in this respect the nasal portion of *Dimetrodon.* The teeth are simple and without the lateral cusps. There is a single large tusk in the upper jaw in the position of a canine. The posterior part of the skull is abruptly truncated, as in the previous suborder.

Lycosaurus was a larger form, with a skull nearly eight inches long. The upper jaw was very convex on the alveolar border, and the lower jaw was correspondingly concave. The whole skull was much depressed.

Cynognathus.—This genus is in some respects the most nearly related of the *Cynodontia* to the *Pelycosauria*, and in others most closely to the succeeding group, the *Gomphodontia.* The general aspect of the skull is that of the *Pelycosauria.* The cranial region is abruptly terminated; the jaws are curved on the alveolar border, and the teeth are divided into the separate regions. There is, however, only a single temporal arch that is almost certainly made up of the two primitive arches combined. The teeth are cuspidate, with a single tubercle in front and another behind. These are developed on the sides of the tooth as well as on the front and rear giving the first appearance of the tubercular type of the teeth. The palate bones also present a step in advance of the reptilian form. They are extended and unite in the median line, thus forming a separate cavity for the nasal organs. This, however, does not extend very far back, ending at about the middle portion of the roof of the mouth. The occipital condyle is almost double, the two sides being greatly developed at the expense of the median portion. The whole skull of one of the best known species was about fifteen inches long. The vertebræ, pelvis, and limb bones all show the same characters as the preceding group.

Gomphodontia.—The suborder is thus described by Seeley: "The *Gomphodontia* comprises animals with a Theriodont type of dentition, in which the molar teeth are expanded transversely, and have more or less tuberculate crowns of the type shown in *Diademodon.* The superior and inferior teeth are opposed to each other, and the crowns become worn with use, as in the Ungulate and other Mammals, and as in the Iguanodont reptiles. The canine teeth of the upper jaw appear to be worn at the extremities.

"It (the skull) appears to show mammalian proportions and aspect, in the definition of the large temporal vacuities, by a

zygomatic arch, which is formed by the molar and the squamosal bones, and in the separation of those vacuities from each other by a long, narrow, parietal crest. The orbit of the eye, however, is separated from the zygomatic vacuity by a postfrontal bone, so that the structure is distinct from that which obtains in the 'mammals.'

"There are two well-defined occipital condyles at the back of the base of the skull, united to each other inferiorly in a way that is closely paralleled in some mammals. The hard palate formed by the maxillary and palatine plates terminates transversely in the middle length of the molar teeth in a way that is remarkably like the dental condition of certain Marsupial mammals.

"So far as is known, there is no fundamental difference in the skeleton to separate the *Gomphodontia* from the *Cynodontia*, which may be regarded as related in the same way as are groups of the Marsupials with similarly differing dentition."

The group *Gomphodontia*, as the author of the suborder says, does not obliterate the interval between the mammals and the reptiles, but it does close up the gap to a large extent, and we are well able to see what must have been the few final steps that led to the formation of the *Mammalia*. If the quadrate should entirely disappear and the teeth take on ever so little a difference in form, if the bones of the squamosal region should coalesce, as they have almost done already, there would be no place where we could say this is reptile and this is mammal.

The known genera of this suborder are: *Tritylodon*, *Trirachodon*, *Diademodon*, *Gomphognathus* and *Microgomphodon*.

Tritylodon was originally described as a mammal by Owen. It is known only from the imperfect upper portion of the skull. The skull was long and rather narrow; the anterior nares were joined in one external opening; there were no incisor teeth, but a large pair of canines; the molar teeth were broad and supplied with three rows of tubercles; between the canines and the molars there was a long diastema. The specimen is from the Permian of Basutu-land in South Africa. From the same region

Seeley has described the forearm and forefeet of an animal that he called *Theriodesmus* which may belong to *Tritylodon*.

From the upper Triassic of Wurtemberg, near Hohenheim, Fraas has described a single tooth that bears a very striking resemblance to the molar teeth of *Tritylodon*. This tooth he calls *Triglyphus*.

Diademodon is from the eastern part of the Cape region of South Africa; it is known from an imperfect skull showing the palate and the teeth. The characteristic part of the skeleton is the broadly tubercular teeth; they are flat or cupped on the grinding face, with the edges showing many small tubercles; the appearance is not unlike that of the pig or the human tooth.

In other characters than the teeth the genus is very similar to the *Cynodontia*, and the chief point of interest to us is the evidence of a gradual progression towards a more and more complicated style of tuberculate molars that is to culminate in the multituberculate type of the most primitive mammals.

Trirachodon.—Of this genus Seeley says: "The skull in this genus has a most remarkable mammalian aspect, in form and proportion of every part. It was four inches long, as preserved, and about two inches wide behind. The orbits are circular, placed slightly in advance of the middle length of the head. The snout appears to terminate conically, rounded above and tapering forward, with a rounded alveolar margin. . . . . Each molar crown has three transverse, conspicuous ridges, but the middle ridge is the most elevated, and rises as a distinct cusp on the external and on the internal margins."

Microgomphodon.—This genus is known from the portion of a skeleton preserved in a slab of rock from the same region as the preceding genera. The teeth are the most characteristic portion; they are much enlarged in the transverse direction, being nearly or quite as long as wide. The surface is slightly convex from before backwards, and is covered with small tubercles, that become much larger at the external and the internal edges. The form is a small one, the largest teeth having a transverse diameter of two-tenths of an inch only and an antero-posterior

of one-tenth. The ribs are of the usual broad character of the African Permian reptiles generally, and the pelvis shows the broad ischium and pubis of the *Cynodontia.*

Gomphognathus.—This is perhaps the most interesting of the South African reptiles, because of its great similarity in structure to the *mammalia.* This is most apparent in the double occipital condyles, in the length of the separated nasal cavity, in the division of the teeth into premolars and molars, as well as into the major divisions of the dentition, the incisors, canines, and molars. The whole aspect of the skull is strikingly mammalian. The molar teeth have a posterior cusp or heel, and the outer edge is raised into a sharp cusp.

The geological and the geographical relations of this group are of extreme interest. They range in time only through the Permian and the Triassic. They are known only from a very limited region in South Africa, and from an even more limited region in the United States, where indeed the whole range of the fossiliferous beds is within the limits of four counties. Besides these two regions there is the case of the single tooth from the Wurtemberg region.

Dinosauria.—The *Dinosauria*, or the *Dinosaurs*, is the name applied to a large group of extinct animals that were confined to the Mesozoic time exclusively. When the existence of the group was first recognized by Owen, in 1839, he considered it as a well-defined order. Later discoveries have shown that under the original description there must be placed in the order animals of the most diverse character, so that it is becoming apparent that the old group must be abandoned and another, or, more correctly, several others, substituted. The very comprehensive character of the order, as usually defined, may be seen from the following characters given by Marsh, Zittel, Haeckel, and other writers on the group.

Premaxillary bones separate; upper and lower temporal arches present; no teeth on the palate; rami of the lower jaws united by cartilage only; vertebræ procœlus, opisthocœlus, or amphicœlus; sacral vertebræ united; scapula elongate; no pre-

coracoids; coracoid small; ilium greatly prolonged in front of the acetabulum; the ischia joining on the median line below; the pubis often with a strong posterior process, the post-pubic process. The form of the body and the head varies greatly in the different forms, being sometimes like that of the crocodiles and at other times like that of the birds, reptiles, or even the mammals. In the majority of the forms the hind limbs exceeded the anterior ones in size, and were used more commonly in walking; in some of the later and more specialized forms the anterior pair of limbs had lost the ambulatory functions entirely and had become wholly prehensile in character. The feet were as variously developed as the other parts of the body; in some of the forms inclining towards the ungulate type and in others developing well-formed claws. The dentition varied from the carnivorous to the herbivorous, some forms having strong recurved tusks, with serrated anterior and posterior cutting edges, and others with the jaws filled with close-set grinding teeth. The external appearance presented as many differences as the skeleton; in size they varied from that of the great herbivorous forms much larger than an elephant to the little leaping carnivorous forms no larger than a jack-rabbit. The skin of some was smooth and of others thickly covered with bony dermal plates and excrescences. Some walked erect, using the strongly developed tail as an aid in supporting the body, while others were entirely quadrupedal.

This great range of characters has led to a great number of different schemes of classification, in most of which the order *Dinosauria* has been recognized as a definite group, but it is constantly growing more difficult to keep the heterogenous assemblage together. Through all the later attempts at classification there has been a recognition of three types of structure that have been regarded as of ordinal, subordinal, or family rank by the various authors. These three divisions were regarded by Baur as distinct groups having nothing to do with each other.[1]

[1] BAUR, "Remarks on the Reptiles generally called Dinosaurs," American Naturalist, May 1891.

In his last classification of the *Dinosaurs*,[1] Marsh recognizes essentially the same group as Baur, but considers them as orders of the subclass *Dinosauria*. These three groups are called *Theropoda*, *Sauropoda*, and *Predentata;* the same groups were called by Baur *Megalosauria*, *Cetiosauria*, and *Iguanodontia*.

It is without the scope of the present article to discuss the intricate taxonomy of this group, and it will perhaps suffice to recognize the three distinct groups and to know that the tendency at the present is to consider the *Dinosauria* as an unnatural order and to speak of the *Dinosaurs* as a very loosely connected group made up of several distinct and well-defined groups.

THEROPODA (*Megalosauria*). — Brain case incompletely ossified in front; no ossified alisphenoid; an epipterygoid (columella); premaxillaries not excluding maxillaries from the nasal opening; jugal connected with the alveolar border of the maxillaries on the same plane; quadrato-jugal free from the maxillary; quadrate directly backwards; mandible without predentary bone; dentary without coronoid process; sacral vertebræ with the ribs joined intervertebrally; diapophyses of the vertebræ without connection with the ribs, but reaching out to and joining the ilium; pubes directed forward and strongly united at the distal end; limbs with the bones frequently hollow; posterior limbs much the largest; feet terminated by claws that are prehensile in the fore foot; locomotion mainly bipedal and digitigrade.

Anchisaurus, the oldest one of this group, as well as the oldest known *Dinosaur*, is from the Triassic Red Sandstone of the Connecticut Valley. A nearly perfect skeleton was obtained from these rocks in the vicinity of Manchester, Conn., in 1884. Previous to this time there had been fragments of skeletons obtained from the Triassic rocks of Pennsylvania and Prince Edward's Island, in Canada, as well as from the same deposits in the Connecticut Valley that in all probability belong to the same genus.

[1] "The Dinosaurs of North America," 16th Ann. Rept. of the Director of the U. S. G. S., Pt. I.

The skull was very birdlike in general outline ; both the upper and lower jaws were full of small, sharp teeth that inclined toward the anterior ends of the jaws, and were not differentiated into molar and incisor regions (this feature occurs only in the most specialized of the reptilia) ; the fore limbs were much smaller than the hind limbs, but were quite large in comparison with those of the more specialized forms of later time, and perhaps took a large part in walking, although the hind limbs undoubtedly were the most largely used; all the bones of the limbs were hollow, and had very thin and solid walls, as in the birds; the fore foot had five digits, only four of which were functional; the hind limb had four toes on the foot, the fifth being a mere rudiment and the first much smaller than the others, so that the track would have been that of a three-toed animal. It is altogether probable that many, if not all, of the so-called bird tracks of the Connecticut Valley sandstone were made by these animals. One species had a length of nearly six feet, while another was much smaller, no larger than a "small fox."

Thecodontosaurus is one of the few European Triassic *Dinosaurs* that are known. It is from the Rhaetic of Bristol in England. The form is known from teeth and from portions of the skeleton; the teeth are of the typical carnivorous type, and are serrated on the anterior and the posterior borders.

Zanclodon (*Plateosaurus*) is from the Trias of many parts of Germany. The teeth are curved backward as in the preceding genus, and are serrated on the anterior and the posterior edges; the vertebræ are deeply bi-concave, and are very much longer and smaller in the cervical than the dorsal region; the limbs were short and strong and the jaws were long and curved. Only a part of the skeleton is known, although several specimens have been discovered; altogether there are about sixty vertebræ preserved in series, and these have a length of nine feet; the form is remarkable in being one of the few *Dinosaurs* that have bi-concave vertebræ.

Epicampodon is a form from the Trias of the East Indies,

Panchet group. It is known only from a few teeth having the same character as those of the previously described forms.

Massospondylus is the name given to certain remains from the Trias of South Africa, Karroo formation, and East India, Panchet group, that are known from a few teeth of the usual recurved type and some deeply bi-concave vertebræ.

Arctosaurus is from the northern part of North America, and is known only from a single vertebra.

Compsognathus from the upper Triassic of Bavaria, Lithographic Slates of Kelheim, was very similar in many respects to *Hallopus* of the Jurassic; the hind limbs were much smaller than the fore limbs, and the lower part of the leg showed the same adaptation to a leaping form of progression. The bones were all hollow and very compact in structure; the cervical vertebræ were numerous, forming a long neck, to which the head was joined at right angles. The astragalus was very closely joined to the end of the tibia, much as in the birds. Many authors have seen in this form the direct ancestors of the birds, but there are still wanting certain links to join the two forms together.

This closes the list of the well-known Triassic *Dinosaurs*. It will be noticed that they are all of the carnivorous type, though indications of a larger form of the herbivorous type are mentioned by Marsh. This author says of the distribution of the Triassic *Dinosaurs:* "It is a remarkable fact that the seven skeletons of Triassic *Dinosaurs*, now known from the eastern part of this continent, are all carnivorous forms and of small size. There is abundant evidence from large footprints that large herbivorous *Dinosaurs* lived here at the same time, but no bones nor teeth have yet been found. In the western part of the continent a few fragments of a large *Dinosaur* have been found in strata of supposed Triassic age, but with this possible exception osseous remains of these remains appear to be wanting in this horizon." Footprints "have been discovered in the Triassic sandstones of New Mexico. A few bones of a large *Dinosaur* were found by Professor Newberry in strata apparently of this age in southern

Utah. These remains were named by Professor Cope *Dystrophæus*."

Hallopus, from the Jurassic of Colorado, is remarkable for its development as a leaping form; the femur is much shorter than the fore part of the leg and the metatarsals are greatly elongated, as in the jumping rodents. The whole form was not much larger than a rabbit.

Cœlurus, from the upper Jurassic of Wyoming, was much larger than the preceding genera, being several feet in length. It was of the same jumping type, the fore feet being much the larger. The skull is very imperfectly known. The most remarkable thing about the skeleton is the thinness of the bones and the great cavities that exist in all of them, the ribs even being hollow. The limb bones, the vertebræ, the bones of the pelvis and of the pectoral girdle, are all excavated by large air cavities that must have rendered the skeleton very light. The dentition was of the same carnivorous type as the former genera.

Ceratosaurus, from the upper Jurassic of Colorado, is one of the largest of the *Theropoda*, being about seventeen feet in length. The head was very large in proportion to the body and was quite lizardlike in many respects; there was developed on the anterior portion of the snout a strong bony process that undoubtedly supported a horn during the life of the animal. The bones of the skeleton are very light, having internal cavities such as exist in *Hallopus* and *Cœlurus*, only to a less extent; the hind limb is much larger than the fore limb, so much greater that it is possible that the fore limb was never used for other purposes than those of seizing and holding the prey of the Dinosaur. The bones of the pelvis are anchylosed together, instead of showing the sutures between the bones as in the other forms; this is an essentially birdlike feature.

Allosaurus, *Creosaurus*, and *Labrosaurus* are all from the upper Jurassic of Wyoming and Colorado. The former was one of the largest carnivorous forms of the United States, if not the largest. The total length was about twenty-one feet. Remains that have

been referred by Marsh to these genera have been taken from the Potomac Beds of Maryland.

Lælaps was one of the same type of *Dinosaurs* as those already described It is from the upper Cretaceous of New Jersey and Montana. The animal had a length of about fifteen feet.

The European forms presented scarcely less varied types than the American forms, but the bones are less well preserved and the skeletons consequently less well known. Prominent ones are *Megalosaurus* and *Streptospondylus*. The first, from the Jurassic of England and many parts of the continent, is also known from the Jurassic beds of Colorado and from the Cretaceous of the East Indies. It was one of the largest of the *Theropoda*, the femur being over a meter in length.

Aristosuchus, from the Wealden of England, is somewhat similar to *Cœlurus*, having similar cavernous vertebræ and light limb bones

Tanystrophæus, from the Muschelkalk of Bayreuth, is remarkable for the extremely elongated cervical and caudal vertebræ. They are eight or ten times as long as they are broad, and are hollow as in *Cœlurus*. The same form is known from the Triassic rocks of New Mexico.

SAUROPODA (*Cetiosauria*).— Brain case completely ossified in front; a well developed alisphenoid; no epipterygoid (columella); premaxillaries not excluding the maxillaries from the nasal opening; jugal and quadrate forming a continuation of the posterior border of the maxillary in the same plane; quadratojugal in connection with the maxillary: quadrate directed forward; mandible without predentary bone; dentary without coronoid process; sacral ribs attached to a single vertebra; neural canal much expanded in the sacrum; limb bones without medullary canal; the fore and hind limbs nearly of the same size; feet plantigrade; the termination of the toes in nails or hoofs rather than in claws.

The order is practically unknown in Triassic time, but in the

Jurassic reached a very great development, both in numbers and in diversity of forms.

Brontosaurus is from the upper Jurassic, in the vicinity of Lake Como, in Wyoming. It is the largest *Dinosaur* known, as well as the largest of the animal creation; the whole beast, from tip of snout to tip of tail, measured nearly sixty feet. The head was very small in proportion to the rest of the body, being less than the fourth cervical in size. The tail and the neck were long and quite strong. The tail was over half as long as the rest of the body; the dorsal vertebræ had a short antero-posterior extent, but were quite broad. A hole under the transverse process of each side opened into a large cavity in the body of the vertebra, probably for the purpose of reducing weight. The pectoral girdle is represented by the usual elements, but the coracoid is very much smaller than the scapula and the sternum is composed of two pieces, one on each side of the median line as in the embryos of birds. The neural canal is greatly enlarged in the sacral region; this enlargement begins even in the cervical region, so that it would have been possible to have drawn the whole of the brain down through the neural canal.

It is difficult to see how an animal that had reached the unwieldy size of the *Brontosaurus* could have supplied itself with food; the very small head and rather weak dentition would seem to render the actual task of getting a sufficient supply of food into the enormous body a very difficult one, even granting that the food was most plentiful; but if the animal was compelled to search to any extent for its supplies the work must have been an almost constant one. This is especially true because the food was entirely vegetable, and the proportion of such food necessary to support a body is much greater than the more condensed food of the carnivorous forms. The animal was in all probability semi-aquatic in its habits and lived for a good part of the time in the waters of the oceans and the lakes of the later Jurassic and the early Cretaceous time. That they suffered much from their great bulk is evident from the condition in which the skeletons are found; they are in many cases complete and undisturbed,

showing that the animal was mired down in some hole or on the uddy bank of some body of water.

Camarasaurus (*Atlantosaurus*) was very similar to the preceding, differing in the fact that the sacral and the caudal vertebræ are solid, instead of having the large vacuities that are found in the same bones of the preceding genus and in the vertebræ of the anterior region of this genus. The scapula of one specimen measured one and a half meters, and the femur nearly two. From the Upper Jurassic of Colorado.

Morosaurus, *Allosaurus*, and *Apatosaurus* are all forms that are distinguished by minor characters of the vertebræ, and limbs from the preceding genera. They are all from the same horizon as the preceding, in Wyoming and Colorado.

Cetiosaurus is from the Upper Jurassic of England ; the form is so similar to that of the various American forms that Baur has suggested that all the genera from Colorado and Wyoming are possibly the same as the English one. The skeleton is only partially known, the head being missing in all the known specimens. It was nearly thirty-five feet in length, with about the same proportions of the fore and hind limbs, and the vertebræ as *Brontosaurus*.

Ornithopsis, from the Upper Jurassic of England and France is very similar to *Cetiosaurus*, but shows large vacuities in the sides of the dorsal vertebræ.

Diplodocus, from the Upper Jurassic of Colorado and Wyoming, is remarkable for the long cervical and caudal vertebræ. The vertebræ were very light and hollow, those of the sacral region especially. The chevron bones, instead of being simple, with only the single V-shaped branch, were composed of two V-shaped branches that extended forward and back, and were united at the proximal extremities. The jaws were edentulous, except at the anterior ends, and these were supplied with long, slender teeth that were constantly shed and renewed from below, a specimen with as many as seven successive teeth in various stages of development being known.

Titanosaurus is the name given to certain large vertebræ, from

the Middle Cretaceous layers of the East Indies. The same vertebræ have been found in the Cretaceous of England.

A very imperfectly known form, *Aepysaurus*, is found in the Cretaceous of France.

Imperfect remains have been described from Patagonia, *Argyrosaurus* and *Titanosaurus*, and from Madagascar *Bothriospondylus*.

Some teeth and parts of vertebræ have been discovered in the upper part of the Potomac formation of Maryland.

It will be seen that the *Sauropoda*, as far as we know them now, are for the most part confined to the continent of North America. The few forms that are found in the other parts of the world indicate the wide extension of the group, but in these there is no indication of such a degree of specialization as was attained by the North American forms. This continent seems to have been the home of the group and the seat of their greatest development.

PREDENTATA (*Iguanodonta*).— Brain case completely ossified; a well-developed alisphenoid; no epipterygoid (columella); premaxillaries, with a posterior outer process extending between the maxillaries and the nasals, excluding the maxillaries from the nasal openings; jugals fixed to a special process outside of the alveolar process of the maxillaries; posterior border of the maxillaries free, not attached to the jugal or the quadrato-jugal; quadrate directed forward; the anterior end of the mandible furnished with a distinct predentary bone; dentary with a greatly developed coronoid process; sacral vertebræ, with the ribs and the diapophyses attached, and the ribs joined to two vertebræ (intervertebrally); pubis consisting of two branches, the anterior one, ectopubis (pectineal process, prepubis) extending far forward and joined with the one of the opposite side by suture; the posterior one, the entopubis, extending far backward, and lying parallel to the ischium, is well developed in some forms, but in others rudimentary; illium much extended in front of the acetabulum, and also reaching far behind. In some forms of this suborder the fore and hind limbs were of nearly equal size,

while in others the hind limbs were nearly as large in proportion to the front limbs as in the *Theropoda;* the feet were armed, in the majority of cases, with flat claws, or hoofs. The dentition shows that the animals were herbivorous in diet, and the mouth is, in some forms, crowded full of teeth. This group did not develop the enormous size of the preceding group, but sought protection in the development of a bony armature that rendered them, in many cases, safe from the attacks of the carnivorous forms.

Stegosaurus.—The jaws were furnished with teeth in the posterior portion only, the premaxillaries being edentulous and probably covered with a horny beak that served the animal in gathering the plants which formed its food. The teeth were flattened sideways, and the crowns were serrated ; the limbs, bones, and the vertebræ were solid ; the fore and hind limbs were of the same size ; the neural processes of the dorsal vertebræ were quite high, and supported the ribs from near the apex ; the feet were plantigrade, and the toes terminated in broad, hooflike claws. The most remarkable thing about the form was the fact that there were developed in the skin of the back and sides great, broad plates of bone that possibly stood up as a median ridge along the back. All the known specimens are from the Upper Jurassic of Colorado and Wyoming.

Camptosaurus, *Laosaurus*, *Dryosaurus*, and *Nanosaurus* are all from the same horizon and the same localities as *Stegosaurus.* They resemble that form in the arrangement of the pelvis, the bones of the skull, and all the essential features of the group, but differ in many external characters. The hind limbs are much larger than the fore limbs, and seem to have monopolized the function of progression ; the fore feet are very small, and could only, under peculiar circumstances, have served as organs of locomotion. There were five functional digits on the fore feet and only three on the hind foot, so that the tracks would have been the same as those of a large bird, and it is very probable that the tracks in the Triassic sandstone of the eastern part of the United States may be tracks of these or of related forms,

instead of birds, as originally supposed. The bones are all hollow, and the whole skeleton was very light. There was an almost complete absence of the dermal armor that characterized the *Stegosaurus;* the whole lightness of the skeleton is incompatible with the weight of such a covering, and it is likely that the animals sought safety in flight, where the former genus trusted to the impenetrability of its armor. The largest of the four genera, *Camptosaurus*, was about twenty feet long, and the smallest, *Nanosaurus*, was only three or four. The last genus is the lightest and the most birdlike of all the *Dinosaurs*.

Dystrophæus is the name given by Cope to the incomplete remains of a *Dinosaur* from the Triassic rocks of Utah. There is preserved only the portions of the hind limb but these show that the animal had only three functional digits on the hind foot and that it was closely related to the *Camptosaurus*.

Teeth from the Potomac formation, evidently belonging to this group have been described by Marsh and Leidy as *Priconodon* and *Paleoscincus*.

Euskelosaurus from the South African beds is too incomplete to be definitely placed anywhere, but is generally placed among these forms.

Scelidosaurus is from the lower Lias of Dorsetshire in England. It was very similar in many respects to *Stegosaurus*, having the same quadrupedal locomotion and the same solid form of the bones but the dermal armor was reduced to a single row of small ossicles down the median line of the back. The whole form was nearly twelve feet long.

Agathaumus from the Upper Cretaceous of Wyoming, is one of the most peculiar of this peculiar group of animals; with the same bodily characters of the trunk as the *Stegosaurus*, minus the dermal plates, the interest of the form centers in the enormous development of the protective armature of the skull. The bones of the posterior cranial region were developed as an enormous cape that extended back over the shoulders; around the edges of the cape there was a series of smaller bones. The frontal portion of the superior aspect of the skull was protected by the

development of three large horns, two of these, the largest, projected from the superior edges of the orbital rims, the others from the anterior part of the snout. One skull taken from the Laramie Cretaceous of Converse county Wyoming, was eight feet from the tip of the snout to the tip of the posterior edge of the skull, and weighed, with the matrix of sandstone, 3600 pounds. The teeth were set in a single row in the jaws and were provided with two roots, a rather peculiar condition in the reptiles. The teeth were transverse and presented broad grinding surfaces. The whole body was stout and elephantine in proportions; the skin was undoubtedly furnished with small dermal ossifications spread through its surface. The tail was long and heavy. The animal must have been, according to Marsh, twenty-five feet long and about ten high.

Torosaurus from the same horizon as the last was smaller, but still quite large, as one skull measured five and a half feet across the top. The most remarkable thing about this form was the great posterior development of the capelike portion of the skull. It extended much farther back than in *Agathaumus* and was perforated by two large fontanelles in the posterior part. The whole plate is much thinner than in the other form.

Claosaurus is from the same region as the preceding and bears about the same relation to those forms that *Scelidosaurus* does to *Stegosaurus*, that is, the general characters of the body are the same, but the peculiar specialization has disappeared. This animal developed the posterior limbs at the expense of the anterior ones, as organs of locomotion. Oddly enough the front feet did not assume the function of grasping organs as in the *Theropoda*, which assumed the bipedal form of locomotion, but retained the broad terminal phalanges that indicate the possession of hoofs on the front feet even after they had grown so short that they could not have reached the ground. The hind feet possessed three functional digits as in *Agathaumus*. The mid-dorsal series of vertebræ was strengthened by the presence of many long ossified tendons that extended for some distance on each side of the neural spines. The limb bones were solid.

The whole animal attained a length of about thirty feet and was probably about fifteen high when it stood erect.

Hadrosaurus is from the same region as all the forms just described and presents the peculiar feature of a flattened snout, resembling the bill of a duck, or the snout of the Australian mammal, *Ornithorhynchus*. Only the skull is well known. The anterior ends of the jaws were edentulous, and were probably covered by a horny sheath; the posterior portions were filled with a large number of teeth that were disposed in rows, and were successional in arrangement so that as fast as the old teeth were worn out new ones, developed in the sides of the jaw, came in to take their places. In one specimen Cope counted six hundred and thirty teeth on each side of the upper jaw and four hundred and six on each side of the lower jaw, making a total of two thousand and seventy-two. The animal was probably aquatic in its habits of feeding, and used the ducklike bill much as the bottom feeding aquatic birds do in gathering up the ooze and slime that contain their food. The fragments of the skeleton that are known indicate that the animal had the same relative proportions of the fore and hind limbs as *Claosaurus*.

Agathaumus, most generally, but erroneously, called *Triceratops*, *Torosaurus*, *Claosaurus*, and *Hadrosaurus* are all from the Upper Cretaceous, the Laramie, and from a very limited region in the northeastern portion of Converse county in Wyoming. A few remains of these forms have been found in near-by portions of Wyoming and Montana.

Iguanodon is the European representative of the *Predentata*. It is one of the few members of the group found outside of the United States. It was of the bipedal type, the hind feet being larger than the fore feet and the whole hind limb showing the more robust character so common in the American forms. There were three functional toes on the hind foot and three on the fore foot, but there were two, the first and the fifth, on the fore foot that are entirely lacking on the hind foot. The first digit on the fore foot was modified in a most peculiar manner into a short and strong spurlike process that stood out at right angles to

the rest of the digits. The vertebral column was strong with well developed neural processes on the dorsal vertebræ which were further strengthened by ossified tendons that aided in moving the heavy tail. The postpubis was long and extended back almost to the distal extremity of the ischium. The teeth were of the same type as the American forms, broad laterally, with serrated edges, and adapted to the trituration of vegetable food. There was no dermal armor as far as known but it is possible that there were small bony ossicles developed in the skin. The animal reached a length of thirty feet in the largest genus and about half of that in the smallest. It is known from the Wealden of England and France, the most important deposit, however, is from the same horizon in the neighborhood of Bernissart, in Belgium, from which region a large number of skeletons have been taken, the majority of them in a very perfect state of preservation.

A description of the *Dinosaurs* would not be complete without some mention of the fossil tracks in the Triassic sandstones of the eastern part of the United States. These are typically developed in the rocks of the Newark group in the valley of the Connecticut River, and are also found in these same rocks where they appear in Pennsylvania, Virginia, and North Carolina. A very large number of these impressions have been taken from the Connecticut region, and over a hundred separate species have been named from them. They are almost all three-toed forms and range from about an inch in length to over a foot. They are found associated with amphibian tracks. The course of the tracks may, in some instances, be traced for many feet or yards, and the length of stride and the character of the feet of the two sides can be clearly made out. The majority of the impressions show that the animals walked on the hind feet most of the time, only occasional traces of the front feet being found. In some cases a long groovelike track indicates where the tail of the animal was dragged through the mud. Because of the three-toed character of the tracks and the peculiar resemblance to the tracks of birds they were originally described by Hitchcock as bird tracks (*Ornithichnites*).

Translating very freely from Zittel's *Handbuch*, we have the following summary of the range and distribution of the *Dinosaurs:*

In general we may say that Europe and North America were, during the Triassic, Jurassic, and Cretaceous times, the home and the region of the greatest development of the *Dinosaurs.* From the East Indies only incomplete remains are known from the Trias and the Cretaceous, and from South Africa, only enough remains to say that there were *Dinosaurs* there. In South America and Australia the remains of these animals are, as yet, completely unknown.

Although the largest number of forms as well as the most perfectly preserved remains are known from the United States, Europe affords many specimens of all the principal groups. The American *Sauropoda* are represented in Europe by *Cetiosaurus, Ornithopsis* and an incompletely preserved Cretaceous form. The *Zanclodontidæ* parallel to some extent the *Anchisauria.* The *Megalosauria* of Europe are represented in this country by *Allosaurus, Lælaps*, and several less well-known forms. The *Ceratosauria* are unknown in the Old World, and the *Cœluria*, hollow-boned forms, are represented by *Calamospondylus* and *Aristosuchus. Tanystrophæus* belongs to both the Old and the New Worlds. The European *Compsognathus* is found in the *Hallopus.* Among the *Predentata* the *Scelidosauria* are confined to Europe while the *Stegosauria* are mostly American. *Omosaurus*, if not a synonym of *Stegosaurus*, would be a European representative of this group. The forms from the Laramie Cretaceous are all confined to the American continent.

From a geological standpoint the original distribution of the *Dinosaurs* was practically contemporaneous, though even in the Trias there were well defined areas containing differentiated forms, and this differentiation by local development was accentuated in the Jurassic and Cretaceous. Animals from the two continents frequently belong to the same families but seldom to the same genera and species.

Perhaps the most peculiar thing about these forms is the sudden and complete destruction of the whole order at the end of the Mesozoic time. The Cretaceous rocks just at the end of the period show that there was a very large number of individuals as well as species, but the earliest of the Tertiary series are as free from their remains as the most recent formation. There is no cause for this sudden extinction of a great group unless it was a climatic one, and even this is not indicated by any change in the vegetable life of the two periods.

Below is a list of the various genera of the Dinosaurs arranged to show their systematic and time relations.

	Triassic	Jurassic	Cretaceous
THEROPODA	*Anchisaurus*	*Cœlurus*	*Lœlaps*
	Zanclodon	*Ceratosaurus*	*Ornithomimus*
	Epicampodon	*Allosaurus*	*Megalosaurus*
	Massospondylus	*Labrosaurus*	
	Arctosaurus	*Creosaurus*	
	Tanystrophœus	*Megalosaurus*	
		Streptospondylus	
		Aristosuchus	
		Compsognathus	
		Hallopus	
SAUROPODA		*Brontosaurus*	
		Camarosaurus	
		Morosaurus	
		Apatosaurus	
		Cetiosaurus	
		Ornithopsis	
		Diplodocus	
		Titanosaurus	
PREDENTATA	*Dystrophœus*	*Stegosaurus*	*Agathaumus*
	Euscelosaurus	*Camptosaurus*	*Torosaurus*
		Laosaurus	*Claosaurus*
		Dryosaurus	*Hadrosaurus*
		Nanosaurus	
		Scelidosaurus	

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Baur, G. Remarks on the Reptiles Generally called Dinosauria. Am. Nat., May 1891.

Ballou, W. H. Strange Creatures of the Past. Century Magazine, November 1897. (Contains many good illustrations of Dinosaurs.)

EDITORIAL.

THE fiftieth anniversary of the American Association for the Advancement of Science was held at Boston, August 22 to 27. The total enrolled attendance was 903, new members 273. The number of papers read before the Geological Section was 29; before the Geological Society 19; before the National Geographic Society 8; making the total of geologic and geographic papers 55.

The titles of the papers were as follows:

VICE PRESIDENTIAL ADDRESS.

Glacial Geology in America. By Professor H. L. FAIRCHILD, Rochester, N. Y.

BEFORE THE GEOLOGICAL SOCIETY OF AMERICA.

1. Some Features of the Drift on Staten Island, N. Y. By ARTHUR HOLLICK, Columbia University, New York, N. Y.

2. Loess Deposits of Montana. By Professor N. S. SHALER, Cambridge, Mass.

3. Glacial Waters in the Finger Lake Region of New York. By Professor H. L. FAIRCHILD, Rochester, N. Y.

4. The Stratification of Glaciers, with lantern views. By H. F. REID, Baltimore, Md.

5. Evidences of Epeirogenic Movements Causing and Terminating the Ice Age. By WARREN UPHAM, St. Paul, Minn.

6. Clayey Bands of the Glacial Delta of the Cuyahoga River at Cleveland, O., compared with those in the Implement-bearing Deposits of the Glacial Delta at Trenton, N. J., with lantern views. By Professor G. FREDERICK WRIGHT, Oberlin, O.

7. The Middle Coal Measures of the Western Interior Coal Field. By H. FOSTER BAIN and A. T. LEONARD, Des Moines, Ia.

8. The Principal Missourian Section. By CHARLES R. KEYES, Des Moines, Ia.

9. Tourmaline and Tourmaline Schists from Belcher Hill, Jefferson county, Colo. By HORACE B. PATTON, Golden, Colo.

10. Magmatic Differentiation in the Rocks of the Copper-bearing Series. By ALFRED C. LANE, Houghton, Mich.

11. The Volume Relations of Original and Secondary Minerals in Rocks. By Professor CHARLES R. VAN HISE, Madison, Wis.

12. Note on a Method of Stream Capture. By ALFRED C. LANE, Houghton, Mich.

13. The Development of the Ohio River. By Professor WILLIAM G. TIGHT, Granville, O.

14. Classification of Coastal Forms. By F. P. GULLIVER, Southboro, Mass.

15. Dissection of the Ural Mountains, with lantern slides. By F. P. GULLIVER.

16. Note on Monadnock. By F. P. GULLIVER.

17. Spacing of Rivers with Reference to the Hypothesis of Base Leveling. By Professor N. S. SHALER, Cambridge, Mass.

18. The Continental Divide in Nicaragua. By C. WILLARD HAYES, Washington, D. C.

BEFORE THE GEOLOGICAL SECTION OF A. A. A. S.

1. Outline Map of the Geology of Southern New England. By Professor B. K. EMERSON, Amherst, Mass.

2. Basins in Glacial Lake Deltas. By Professor H. L. FAIRCHILD, Rochester, N. Y.

3. An Exhibition of the Rare Gems and Minerals of Mt. Mica. By Dr. A. C. HAMLIN, Bangor, Me.

4. The Hudson River Lobe of the Laurentide Ice-sheet. By Professor C. H. HITCHCOCK, Hanover, N. H.

5. The Age of the Amboy Clay Series as Indicated by its Flora. By Professor ARTHUR HOLLICK, Columbia University, New York, N. Y.

6. Some Feldspars in Serpentine, Southeastern Pennsylvania. By Professor T. C. HOPKINS, State College, Pa.

7. The Region of the Causses in Southern France, with maps and stereopticon views. By Dr. HORACE C. HOVEY, Newburyport, Mass.

8. The Washington Limestone in Vermont. By Professor C. H. RICHARDSON, Hanover, N. H.

9. Fluctuations of North American Glaciation shown by Interglacial Soils and Fossiliferous Deposits. By WARREN UPHAM, St. Paul, Minn.

10. Time of Erosion of the Upper Mississippi, Minnesota, and St. Croix Valleys. By WARREN UPHAM.

11. Supposed "Corduroy Road" of Late Glacial Age at Amboy, O. By Professor G. FREDERICK WRIGHT, Oberlin, O.

12. Changes in the Drainage System in the Vicinity of Lake Ontario durng the Glacial Period. By Dr. M. A. VEEDER, Lyons, N. Y.

13. Recent Severe Seismic Movements in Nicaragua. By JOHN CRAWFORD, Managua, Nicaragua.

14. Another Episode in the History of Niagara River. By J. W. SPENCER, Washington, D. C.

15. The Age of Niagara Falls as Indicated by the Erosion at the Mouth of the Gorge. By Professor G. FREDERICK WRIGHT, Oberlin, O.

16. A Recently Discovered Cave of Celestite Crystals at Put-in-Bay, O. By G. FREDERICK WRIGHT.

17. Geography and Resources of the Siberian Island of Sakhalin. By Professor BENJAMIN HOWARD, London, Eng.

18. Evidence of Recent Great Elevation of New England. By J. W. SPENCER, Washington, D. C.

19. The Oldest Palæozoic Fauna. By G. F. MATTHEW, St. John, N. B.

20. The Oldest Known Rock. By Professor N. H. WINCHELL, Minneapolis, Minn.

21. The Origin of the Archæan Igneous Rocks. By Professor N. H. WINCHELL.

22. Joints in Rocks. By Professor C. R. VAN HISE, Madison, Wis.

23. Notes on Some European Museums. By Dr. E. O. HOVEY, New York, N. Y.

24. History of the Blue Hills Complex. By Professor W. O. CROSBY, Boston, Mass.

25. Palæontology of the Cambrian Terranes of the Boston Basin. By AMADEUS W. GRABAU, Boston, Mass.

26. Diamonds in Meteorites. By Mrs. E. M. SOUVIELLE, Jacksonville, Fla.

27. The Periodic Variations of Glaciers. By Professor HARRY F. REID, Baltimore, Md.

28. Note on the Occurrence of Tourmalines in Canada. By C. R. ORCUTT, San Diego, Cal.

29. The Agassiz Geological Explorations in the West Indies. By ROBERT T. HILL, Washington, D. C.

BEFORE THE NATIONAL GEOGRAPHIC SOCIETY.

1. The Venezuela-British-Guiana Boundary Dispute. By Dr. MARCUS BAKER, Washington, D. C.

2. Considerations Governing Recent Movements of Population. By JOHN HYDE, Washington, D. C.

3. Some New Lines of Work in Government Forestry. By GIFFORD PINCHOT, Washington, D. C.

4. The Development of the United States. By W J McGEE, Washington, D. C.

5. Atlantic Estuarine Tides. By M. S. W. JEFFERSON.

6. The Forestry Conditions of Washington State. By HENRY GANNETT, Washington, D. C.

7. The Five Civilized Tribes and the Topographic Survey of Indian Territory. By CHARLES H. FITCH, Washington, D. C.

8. Bitter Root Forest Reserve. By RICHARD U. GOODE, Washington, D. C.

The foregoing has been kindly furnished by Mr. Warren Upham, secretary of Section E, A. A. A. S.

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GEOLOGISTS visiting the exposition at Omaha, and teachers everywhere, will find particularly valuable the topographic map of Omaha and vicinity, published by the United States Geological Survey and gratuitously distributed in the Mines and Mining building. The map bears the date of June 1898, and is an example of the excellence of the maps now being made. The main features are the Missouri River bottom land and valley, and the loess topography. The former is a most characteristic bit of river work. The cut-off lakes, the great bends of the river, the sharp bluffs where the stream impinges against the bank, and other features are shown so clearly as to make the map especially valuable in the class-room. The apparent similarity in width of the Platte and the Missouri rivers and the dissimilarity in their valleys, will likewise call forth questions.

It is, however, the loess topography which is most interesting, since within the limits of the quadrangle there is an excellent example of the contrast between the wind-shaped loess near, and the water deposited away from, the vicinity of the stream. On the west side of the river, in Omaha and near it, the map shows open contour, gentle slopes, and obvious erosion topography and a rectangular system of roads. The hills rise easily to 1200 or 1250 feet A. T. Immediately across the river the contours are close, the slopes sharp, the roads follow streams and ridges and disregard land lines, and the hills rise abruptly to 1300 or 1350 feet, A. T. A very characteristic feature, well shown on the map, is the large number of small detached peaks. Another is the interference

with the drainage, as for example in the case of Mosquito Creek. This stream, whose valley is followed by the Chicago, Rock Island and Pacific, and the Chicago, Milwaukee, and St. Paul railways, has a quite well developed flood plain and a broad, open valley in its upper portion. As it comes within the influence of the river loess, the valley is choked and becomes a mere narrow defile. This and the other features mentioned are not exceptional, but are found at quite distinct points along the Missouri,[1] and are of considerable significance in the matter of genesis of the loess. There are numerous other items of interest relative to the map, but sufficient has perhaps been said to call attention to its value. H. F. B.

[1] Geology Plymouth county, Iowa Geol. Surv., Vol. VIII, 1898, pp. 324–332.

Reviews.

STRATIGRAPHY OF THE SOUTHERN OZARKS.

Thickness of the Palæozoic Sediments in Arkansas. By JOHN C. BRANNER. Am. Jour. Sci., (4), Vol. II, pp. 229-236, 1896.

Batesville Sandstone of Arkansas. By STUART WELLER. Trans. New York Acad. Sci., Vol. XVI, pp. 251-282, 1897.

Marine Fossils from the Coal Measures of Arkansas. By JAMES PERRIN SMITH. Proc. American Philos. Soc., Vol. XXXV, pp. 213–273, 1897.

Geological Reconnaissance of the Coal Fields of the Indian Territory. By NOAH FIELDS DRAKE. Proc. American Philos. Soc., Vol. XXXVI, pp. 326-419, 1898.

A decade ago one of our most distinguished writers on geology, commenting upon the progress of geological investigation in this country, drew special attention to the mountainous region of the central Mississippi basin by making the startling statement that that part of our national domain about which least was known geologically was not in the rugged ridges of the Appalachians nor in the great cordilleras of the Far West, but in the very heart of the American continent, in a district where mining had long been carried on—in the Ozark region. Surprising as was the statement it was literally true. Up to that time there had been practically nothing on the geology of this region published. There was no place to which one could turn for information regarding the geology of a tract of more than 100,000 square miles.

Singularly enough, as if anticipating the full force of the remark alluded to, and before the paragraphs had left the press, the states of Arkansas and Missouri established geological surveys the express purposes of which were to solve this very problem. As the result of these official activities there have been published by the two states mentioned

upwards of twenty-five large volumes, all of which are devoted, wholly or in part, to the geology of the Ozarks.

Growing out of this official work, either directly or indirectly, there have appeared from time to time other contributions to a geological knowledge of the region. The Arkansas geologists have been especially active in setting forth information of the greatest value concerning the *terra incognita* of only ten years ago. Branner, Winslow, Penrose, Hopkins, J. F. and H. S. Williams, and Griswold have all given us geological accounts of great interest. The results of their work have been most acceptable. An outgrowth of this same work has been to induce others to take up attractive lines of investigation thus pointed out. At intervals there have been given short sketches that fill in important gaps.

Isolated from all localities where similar rock successions were already carefully studied and were well known, the workers in Arkansas were obliged to set up a geological rock classification of their own. The sequence of terranes could be correlated with those of well-known regions only in the most general way. Much has been done of late to clear up the existing uncertainty of stratigraphic equivalency. The early Palæozoic rocks still resist all attempts of detailed classification and correlation. The Carboniferous has yielded more gracefully. With the latest contribution, by Drake, the last link binding the stratigraphy of the southern region to the northern has been forged.

The "Thickness of the Palæozoic Sediments in Arkansas," by Professor Branner, may be taken as a concise summary of the results of the Arkansas geological survey regarding the sequence and development of the older rocks of the southern Ozarks. The article is accompanied by a small but excellent general geological map of the state, and gives a classification of the formations recognized, and their observed thicknesses. The enormous estimated thickness of the Coal Measures is especially noteworthy. These figures come somewhat in the nature of a surprise, manifestly to the author also, for he takes particular pains to present clearly the detailed evidence upon which he has reached his conclusions. He says: "There is, of course, nothing remarkable about the thickness of any of the Arkansas sediments except in the case of the Lower Coal Measures. So far as I can learn the thickness of the Carboniferous rocks in this section is greater than that of the sediments of the same age in other parts of the country or of the world."

The general section of the Palæozoic sediments is as follows:

Coal Measures or Pennsylvanian	Upper Coal M.	Poteau beds Productive beds	3500 1800
	Lower Coal M.	Barren beds	18480
	"Millstone grit"	- - - - - - -	500
Lower Carboniferous, or Mississippian	Chester, St. Louis, Warsaw	Boston group	780
	Keokuk-Burlington	Batesville sandstone Fayetteville shale Wyman sandstone Boone chert	200 300 10 370
Devonian?		Sylamore sandstone Eureka shale	40 50
Upper Silurian		St. Clair marble	155
Lower Silurian		Izard limestone Underlying beds	285 1750
			28220

The "Marine Fossils from the Coal Measures of Arkansas," by Dr. Smith, is largely a description of species, with comments upon their biologic relationships. Nevertheless, in the introductory portion, the stratigraphy is considered, and the conclusions reached concerning the position of the beds in the general geological column, as thought to be indicated by the fossil evidence, are set forth.

A table is given correlating the Arkansas strata with the Carboniferous deposits of China, India, Russia, South America, and other parts of the world. Done in such a broad way, it is hard to see just what force any extended discussion of this kind can have. Such faunal comparisons are, in general, of great interest in a biological way, and evidence a wide acquaintance with palæontological literature, but, from a geological standpoint, they have, with no reflection on Dr. Smith's efforts, small stratigraphic value. A detailed parallelism with its nearest related areas of Coal Measures, which is the great desideratum to all those at all interested in the geology of the region, and

which appears to have been, in starting out, the main object of the memoir, is the very phase that all would have desired to have discussed more fully. This, however, should not be expected, perhaps, since it pertains more particularly to the purely geological side of the question, and the paper lays most stress on the biologic aspects.

The account of the fossils is a welcome addition to our knowledge of the distribution of the Carboniferous organisms in the Mississippi province. While the list may appear meager, it must be remembered that heretofore only an occasional or straggling form was known from the region. Twenty-one localities yielded fossils. There are represented forty-eight genera and ninety species, some of which are not specifically identified. The "fauna is a poor one, such as one would expect to wander in from deeper waters whenever a slight subsidence made shallow waters a little more habitable. The faunas could not become well established, because the conditions soon reverted to their old state, and the inhabitants of the seas were forced to migrate or be exterminated."

In comparing the fauna with its nearest ally, in Kansas and Nebraska, the conclusion is reached that "there is not sufficient reason for classing the Poteau Mountain beds with the Permian, but their fauna, as well as stratigraphic position, place them very high in the Coal Measures, since they are like the fauna and position of the Mississippi Valley Upper Coal Measures."

The "Batesville Sandstone of Arkansas," by Mr. Weller, treats of the Lower Carboniferous of the northern part of the state. While the greater part of the paper is devoted to the description of fossils, the brief account of the stratigraphy and correlation features is the most important that has yet appeared on the subject. The comparison of the general section of the Lower Carboniferous in Arkansas with that of the typical localities along the Mississippi River shows that the two are essentially identical.

The "Batesville sandstone has the same stratigraphic position in the Batesville section which the Aux Vases sandstone occupies in the typical section, and the lithological characters of the two formations are similar. No fossils have as yet been found in the Aux Vases sandstone, but if a fauna were found a mingling of St. Louis and Kaskaskia species, such as are present in the Batesville sandstone fauna, would be looked for."

The parallelism of the Arkansas section of the Lower Carbonifer-

ous, or Mississippian series, with the one long known farther northward, is as follows:

Typical Mississippi Section	Arkansas Section
Kaskaskia limestone	Boston group
Aux Vases sandstone	Batesville sandstone
St. Louis limestone	Spring Creek limestone
Augusta limestones	Boone chert
Kinderhook beds	St. Joe marble Sylamore sandstone

According to this arrangement the former lines of division in the Arkansas formations will have to be modified considerably. The Kinderhook portion will doubtless need further revision in northern Arkansas.

A "Geological Reconnaissance of the Coal Fields of Indian Territory," by Dr. Drake, connects the Arkansas work with that of Kansas and Missouri. For the first time we are able to understand what relationships the subdivisions that were adopted by the Arkansas geologists, for the Coal Measures, have to those recognized in other parts of the interior province. The sketch-map accompanying the memoir gives the distribution of the formations; and a number of sections still farther elucidate the structure of the region.

A small crystalline area, the Spavinaw granite, discovered by Owen forty years ago, is found to be a dike, fifty feet wide, breaking through the crest of a low anticline of Silurian limestone. As, however, the overlying Lower Carboniferous in the bluffs a few yards away is also tilted in the same way as the Silurian strata, the age of the dike is regarded as post-Carboniferous. Since Owen mentioned the occurrence nothing further has been made known concerning this granite until the recent visit. The results of this examination are important, as they set to rest much speculation. As the granite must have been intruded under a considerable weight of superincumbent strata, it is somewhat surprising that all traces of metamorphic action should have escaped notice. The presence of the epidote would indicate that contact phenomena should be present, at least, in some slight degree.

The Silurian rocks appear only in a few limited areas in the extreme eastern part of the territory. All of these localities are north of the Arkansas River. Areas known to exist in the southern portion of the territory are omitted.

The Lower Carboniferous is well represented, the western boundary being approximately the Neosho River. The beds are continuous with those of northwestern Arkansas and southwest Missouri. The subdivisions recognized are the Eureka shale, Boone chert, Fayetteville shale, Batesville sandstone and the Boston group.

The rest of the Carboniferous is subdivided into Lower Coal Measures, Upper Coal Measures (with two groups, the Cavaniol or coal producing, and the Poteau or barren) and Permian.

The remainder of the paper is taken up with lists of fossils, some descriptions of new species, and a short economic chapter.

The restriction of the term Ozark to the northern part of the uplifted region of Missouri and Arkansas is noticeable. It is, no doubt, convenient to distinguish the northern, slightly folded part from the southern, trans-Arkansas portion, and to designate the latter the Ouachita region. The latter term will be generally used. This should not, however, be to the exclusion of some other name for the whole of the elevated area. The use of Ozark in the restricted sense as has been done, without giving any geographical reason, at once arbitrarily subdivides the region. The uplift, or dome, is believed to be a great geographic unit, having a definite history that covers the Ouachita district the same as the more northern area. From a geographic standpoint the close folding has no especial influence in the general development nor in determining its broad physiographic nature.

If the two districts are really distinct in their present aspects, when viewed from the genetic and geographic points of vantage, it should be shown that their development is in no way connected, that the history of each has been different, that their present physiognomies are of diverse origin. This has not been done as yet; and no attempt appears ever to have been made in this direction.

On the other hand all the published materials and the known facts seem to point to a very different course of events. After the Carboniferous the region between the Missouri and Red rivers was apparently subjected to orogenic movements—intense and local in the south, moderate and regional in the north. The whole region was then planed down during the Cretaceous or Tertiary, perhaps, practically base-leveled, so as to form part of the great peneplain of the Mississippi valley. The closely folded area appears to have been planed off in the same way as the broad flexures. Subsequent elevation of the

peneplained surface in a broad dome, higher in the south than in the north, set to work again the forces of degradation. In the south greater elevation, highly tilted strata, and soft beds alternating with hard, of the Coal Measures, gave rise to great contrasts of relief. In the north, with less height, gently inclined strata and resistant dolomites and limestones very different relief effects were produced.

The mountains of the Ouachita district appear to have tolerable even tops. In the novaculate region, in the extreme south, where the rocks are very hard, the mountains have only half the height of those a little farther north, but made up of softer beds, or soft layers alternating with harder ones. The great Arkansas River has cut its broad valley through soft shales of the Coal Measures. Everything goes to show that the present aspect of the whole elevated region is the result of one grand recent bowing up.

The correlations of the Coal Measures made by Dr. Drake are of great interest. In the June issue of this journal reasons were given for believing that nearly the whole of the enormous thickness of the Coal Measures of Arkansas was the equivalent of only the Lower Coal Measures of Missouri and Kansas—the Des Moines series. Dr. Drake's notes and map appear to afford conclusive proofs of this view. His great basal sandstone, "Lower Coal Measures," and the productive group (Cavaniol) taken together would appear to represent approximately the Des Moines series. I say approximately, for it is not yet quite certain just what is the upper limiting horizon of the "Cavaniol." On his map, where the western boundary of the latter leaves the territory northward, it meets the lower member of the Bethany limestone—the basal stratum of the Missourian series, and Upper Coal Measures of the western interior coal basin. The presence of marked escarpments at various places beyond this western boundary line are also taken as indications of the southern extension of the Kansas Missourian.

In like manner the Poteau group seems to be the equivalent of that part of the Missourian series of Kansas, below the Wabaunsee shales. Possibly its upper limiting horizon is even lower.

We are certainly deeply indebted to Dr. Branner and his associates for a set of contributions of much more than passing general interest and of inestimable local value.

C. R. Keyes.

The Newark System or Red Sandstone Belt (*of New Jersey*). By HENRY B. KÜMMEL. Annual Report of the State Geologist of New Jersey for 1897, pp. 25–159. Trenton, N. J.

In the corresponding report for 1896 Dr. Kümmel presented a brief report on the Newark system of the western part of New Jersey. He has now extended his work so as to cover the whole of the area of the system within the state, and the present report embodies the results of his fuller studies. As indicated in an earlier number of this JOURNAL, Dr. Kümmel finds the Newark system divisible into three series, the basis for subdivision being lithological, not palæontological. These divisions, commencing below, are (1) the Stockton series, the characteristic beds of which are arkose sandstones and conglomerates; (2) the Lockatong series, the characteristic beds of which are black shales, dark, massive argillites, and gray and green flagstones; and (3) the Brunswick series, consisting primarily of red shale and sandstone. Maps are presented showing the distribution of these several divisions. As a result of the profound faults affecting the western part of the system, the several series do not appear at the surface in single, continuous belts, but are repeated. The disposition of the outcrops is still further complicated by the folding which the beds of the system have suffered. In the eastern part of the state the Lockatong series does not appear, but the Stockton series is found in limited areas on both sides of the Palisade ridge.

One of the interesting facies of the system is the conglomerate which occurs along its northwest border, at and near its junction with the pre-Mesozoic terranes. This conglomeratic phase of the system assumes different aspects at different points. It is now made up chiefly of limestone, now of gneiss; and now of quartzite; but the significant point in the relations of these several phases of conglomerate is the fact that the larger areas of calcareous and quartzite conglomerates do not abut against older formations of limestone and quartzite, but against gneiss instead. The conglomerates are clearly shore deposits, and it is therefore inferred that the conglomerate beds were not derived chiefly from the older formations against which they now lie. It is believed that faulting along the contact of the Triassic system with the older formations is responsible for the lack of correspondence between most of the conglomerates and the formations against which they abut.

Another point of interest and significance is found in the fact that the conglomerates do not occupy a distinct horizon, but that each of the three series in turn becomes conglomeratic as the border of the system is approached. Incidentally it may be inferred that the northwestern extension of the system was never much greater than now, since the shore phase of each series is represented along the present border.

The relations of the igneous rocks of the system also receive much more systematic discussion than in any previous publication. Several small areas of igneous rocks (dikes) heretofore unmapped have been located. While the previous conclusions as to the intrusive character of some of the trap sheets and the extrusive character of others are confirmed, the evidence on which these conclusions rest is so fully detailed, and is in itself so decisive, that further discussion of this point is not likely to arise.

Many of the principal structural features of the Newark system have long been known, but no previous student of these formations has worked out the details of the structure with anything like the fullness shown by the present report. The general monoclinal structure of the system (strike N. 30° to 50° E, and dip 13° or 15° to the northwest) is found to be affected by several broad, gentle flexures, and by a few sharply marked folds, especially in the vicinity of the intrusive sheets of trap and along the greater fault lines. The positions of these flexures are given and their effects on the topography, where beds of unequal resistance outcrop, are pointed out. Even among the gentle folds of the system the axes of flexure sometimes depart from horizontality because of still gentler cross-folds, showing that the forces which deformed the beds were not confined to one direction.

The beds of the Triassic system have long been known to be faulted, but not until now have these faults been worked out in detail. Of the two major faults, one (the Flemington fault) was known before Dr. Kümmel's studies began, while the other (the Hopewell fault) was discovered by him. Both these faults have a throw of several thousand feet, and each causes the repetition of the outcrop of each of the three series of the system. Besides these two principal faults, displacements are believed to exist along the northwest border of the system at more than one point.

Of minor faults there are many. Something like fifty are described, and many figures are given showing in a graphic way the evidence on

which their existence is known. The throw of these minor faults varies from a few feet to several hundred. The faults enumerated are more frequent in the trap than in the shale and sandstone. Since faults are much more easily detected where they affect the trap, owing to the fact that this formation has come to assume the form of ridges since the faulting, it is inferred that minor faults affecting the more homogeneous portions of the sedimentary part of the system may have escaped observation.

But for the faults, the determination of the thickness of the system would be an easy matter. Allowance can be made for the faults which are known, but there is no way of taking quantitative account of those which have not been discovered. Impressed with the fact that there may be many undiscovered faults of slight extent in the homogeneous shales and sandstones, Dr. Kümmel has revised his estimate of the thickness of the system, and now gives the following figures:

Brunswick series, - - - - -	6,000 to 8,000
Lockatong series, - - - -	3,500 to 3,600
Stockton series, - - - - -	2,300 to 3,100
	11,800 to 14,700

The thicknesses of the principal sheets of trap are also given, the thickest being less than one thousand feet. A brief discussion of the conditions of the origin of the system is followed by a résumé of its economic resources.

The report, as a whole, presents in excellent form the results of a piece of work which is not likely to need revision. It is a matter of congratulation that Dr. Kümmel has this year been able to extend his studies over the Triassic area of New York.

R. D. S.

The Geological History of the Isthmus of Panama and Portions of Costa Rica. By ROBERT T. HILL, Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXVIII, No. 5, pp. 151–285. Nineteen plates. Cambridge, 1898.

The results embodied in this report are based on a reconnaissance made by the author for Alexander Agassiz in 1895. In spite of the fact that the region concerned was only reconnoitered, the report adds

much to our knowledge of tropical America. Some of the geographic features which characterize the region have been briefly described by the author in earlier publications, but the geological results of the reconnaissance have not before been published. So far as practicable, Mr. Hill's conclusions are stated in his own words.

In the first place, emphasis is laid upon the independence of the North American, Central American, and South American orogenic systems. The Cordilleran system of North America ends in Mexico, a little south of its capital city. The Andean system of South America has its northern terminus east of the Isthmus of Panama, and has no genetic connection with the mountain ranges of the north coast of South America. If the Cordilleran and Andean systems were extended southward and northward respectively, they would pass each other in parallel lines hundreds of miles apart. The extension of the Andean system would lie not only east of the Cordilleran, but even east of the Appalachians, while the extension of the Cordilleran system would lie in the Pacific, far west of the South American coast.

Between the termini of these orogenic systems, with a trend at right angles to both, lies a third system, called the Antillean. It is this system of mountains which has determined the major topographic features of the Antillean region. The system includes the east-west ranges of the north coast of South America, those of the Isthmus, Central America, southern Mexico, and the Great Antilles. In the Caribbean sea, two east-west submarine ridges, separated by the Bartlett Deep, show that the east-west trend of the crustal corrugations of this region affect the sea bottom as well as the land. Like the greater systems to the north and south, the Antillean system is composed of folded sedimentary rocks, plus volcanic intrusions and ejecta. While each of the major orogenic systems dominates a continental area, the Antillean system "constitutes a mountainous perimeter surrounding the depressed basin of the Caribbean."

The primary geographic features of that part of the continent dominated by the east-west system are 1°, a volcanic plateau near the Pacific coast along the western termini of the ranges of the Antillean system, and 2°, the lower but mountainous area facing the Caribbean, consisting of folded beds of sedimentary rock, associated with igneous. To the north, the western termini of the Antillean ranges are buried by the volcanic rocks, but on the Pacific side of Panama, the Antillean ranges continue across the land area.

The surface of Panama is described as consisting of irregularly rounded mountains and hills, 200 to 1500 feet in height. Their topographic expression is uniform whatever the rock of which they are composed. Lack of systematic arrangement in their distribution is said to be one of their striking features, though an east-west trend is locally observable. Their form and arrangement are ascribed primarily to erosion.

"In common with the whole Central American region south of Yucatan, the Isthmus of Panama presents no such feature as a well-defined coastal plain like that bordering the eastern and southern margin of the United States. . . . . Such occasional levels as may be recognized on either coast are the products of the erosion of the greatly distorted sedimentaries and volcanic rocks. . . . . The Caribbean coast is generally marked by jagged and abrupt bluffs where the sea beats directly against the hills. The indentations are slight and far apart. The same may be said of the Pacific side."

The drainage of the Isthmus is defined as "ancient, mature and autogenous, consisting of deeply incised headwater ramifications drowned in their lower courses toward the sea." Although the drainage of the Isthmus is about equally divided between the two oceans, there is no well defined watershed separating the waters flowing into the Atlantic from those flowing into the Pacific.

The Isthmian region is now undergoing rapid erosion, the result of the excessive rainfall (154 inches in 1894), and of the activity of the waves of the oceans. The topography of the sea bottom on either side points to a former greater expansion of land, and therefore to the fact that the narrow neck of land is, and has been disappearing under the influence of the agencies mentioned. This conclusion is further borne out by the outlying islands, which, by their structure and relations, show themselves to be isolated remnants of the mainland.

Two detailed geological sections are given, one across the Isthmus from Colon to Panama, and the other across Costa Rica. In the Isthmian section, seven structural units are recognized. These are (1) the fringing coral reefs; (2) the coastal swamps of both coasts—elevated plains of sedimentation; (3) the Monkey Hill and Panama benches—elevated base-leveled plains; (4) the folded and disturbed Tertiaries which owe their positions to the series of post-Tertiary (post-Oligocene) orogenic foldings along the Caribbean side of a more ancient nucleal region; (5) the numerous protrusions of basic igneous rocks,

the age of which is not definitely known; (6) the sedimentary rhyolitic and andesitic tuffs, the Panama formation, older than the basic igneous formations; and (7) the granitic rocks, the oldest of the region. The sedimentary rocks of the section fall into three categories: (1) those of supposedly pre-Eocene age, occurring on both sides of the Isthmus; (2) the fossiliferous Tertiary beds of the Caribbean side, and (3) the Pleistocene beds deposited synchronously on both sides.

The rocks of the first of these three classes are so distorted and concealed by later igneous protrusions and deposits that little was learned of their relations. They are composed almost entirely of rhyolitic and andesitic material. The beds of the second class are referable, on the basis of their fossils, to the Eocene and Oligocene, corresponding approximately with the Tejon, Claiborne and Vicksburg formations of the United States. They are composed mainly of muddy sediments with more or less sand, glauconite and lignite. Limestone occurs at two horizons. It is to be specially noted that the Tertiary deposits of the Isthmian section end with the Oligocene (early Miocene), and there is nothing to indicate that sedimentation was in progress in the Isthmian region during the later Miocene and Pliocene epochs. The inference is that "the Isthmian land was of much larger area during these later epochs than in Eocene time or at present." The thickness of the Tertiary system is thought to be as much as 1000 feet, and possibly much more.

The igneous rocks of the Isthmian section consist of (1) granite in ranges having an east-west trend; (2) rhyolitic tuffs and pumice, igneous in origin, but sedimentary in arrangement; and (3) basic igneous rocks, occurring as intrusives, eruptives, tuffs, etc. The basic rocks are younger than the others, but are thought to have been in existence during the deposition of the later Eocene sediments. Other considerations prevent the reference of these rocks to an earlier period, and lead to the conclusion "that the most marked volcanic episode of the Isthmian region took place during the later Eocene epoch." It is thought that there are also late Tertiary syenitic intrusives, which "now form the core of great mountainous protuberances."

Throughout the Isthmian region, the surface red clays conceal all the formations. They are believed to be largely the residuum of rock decay. The extent of this decay is said to be "enormous, extending often to a depth of over 100, and seldom less than fifty feet."

In the Costa Rican sections the principal geological features may

likewise be grouped in seven categories. There are (1) the foundation rocks of ancient quartzites, serpentines, jadeite, and granite, probably pre-Cretaceous; (2) limestones, which are believed to be Cretaceous; (3) basic igneous rocks of Eocene, and possibly of late Miocene age; these rocks conceal most of the older formations and are, in turn, largely buried beneath later volcanics; (4) the marine Tertiary sediments, Eocene to Pliocene inclusive, of the Caribbean side; the early beds of this group are extensively disturbed, elevated and broken through by igneous protrusions; against these deformed and eroded strata the Pliocene beds rest unconformably; (5) a line of volcanoes surmounting the Sierras; (6) the Pleistocene sediments of the coasts, and (7) the "bolsons," base-leveled plains, benches, canyons and other topographic features.

In this section the "bowlder clays" of tropical America are encountered. The study of some of the craters of the region throws some light on the origin of these clays. From the craters fine material, such as scoriaceous ash, is thrown in quantity. With these fine products are also many large bowlders of black, massive igneous rock. Subjected to prolonged decay, this mixture of fine and coarse materials would, it is affirmed, leave a residuum identical in appearance with the bowlder clays. The glacial hypothesis, as an explanation of this formation, is regarded as untenable.

On the slopes of one of the mountains, Irazu, between the altitudes of 7000 and 9500 feet, there is found a fine pulverulent yellow dust, which is "in every way identical in lithological appearance and behavior with the loess deposits . . . . of the Missouri and Ohio." This formation is composed of the minerals common to the lavas of the region, but its mode of accumulation is not discussed.

Comparing the two sections, it is stated that "the Panama section is across an old land now nearly graded to the sea, where vulcanism has been quiescent since the Tertiary time," while "the Costa Rican section presents us a view of an ever-growing land where volcanoes have continued to pile their débris from Cretaceous time to the present."

Under the caption, "The Union of the Continents and the Problems of the Straits," the general relations of the Central American and Isthmian regions are discussed. The meager knowledge at hand indicates that "previous to the vast accumulations of more modern igneous and sedimentary rocks of Tertiary and post-Tertiary age, a foundation of granitic rocks, occurring in east and west arrangement,

existed in the South Isthmian and Central American region, extending in echelon arrangement from the longitude of Trinidad through forty degrees to near that of Acapulco, Mexico, directly across the path of the main continental trends." Palæozoic rocks are known with certainty, in the general area under consideration, in but one region, viz., in the Republic of Guatemala, and the adjacent Mexican border region. Their surface development is certainly very meager south of the United States. Triassic rocks, likewise meager south of the United States, also occur in Guatemala, but Jurassic beds are not known at any point in Central America. Cretaceous strata are much more widely distributed in tropical America; but while they cover most of Mexico, it is doubtful if the two oceans were at any time connected across this country in the Cretaceous period. This conclusion is based on palæontological evidence.

As to the Tertiary beds, the facts now in hand "indicate the existence of a continuous littoral of older Tertiary sediments around the Caribbean side of the tropical American region, and incidentally a preëxisting land which they bordered. . . . . These older Tertiary beds . . . . probably belong to the continuous series of sediments of the Eocene and Oligocene epochs. . . . . The Pliocene formations have not been clearly distinguished . . . . from the Pleistocene. There is an intermittent fringe of alleged Pliocene deposits around the Caribbean coast, unconformably deposited against the older continental mass. . . . . We may infer from the relatively slight area of the marginal development of rocks of this period, and their absence in the elevated or folded regions away from or much above the coast line, that it was just prior to the Pliocene period or during its earlier days that the Caribbean coast line, as a result of the tremendous orogenic processes by which the earlier Tertiary rocks were deformed, practically assumed the slope as we now know it."

In elaboration of this point, it is further stated that the early Tertiary strata have "since their deposition been elevated above the sea to great heights by folding on the Caribbean side of the old Isthmian protaxis until they stand 3000 feet in Guatemala, 5000 in Talamanca, 300 near Colon, and 500 at Cartagena. . . . . In Hayti, Cuba, and Jamaica, these plicated, Cretaceous, and early Tertiary rocks are found at altitudes exceeding 10,300, 8000, and 7250 feet, respectively, above the ocean. The east and west strike both of the Tertiaries and of the basic igneous rocks along the northernmost coast of South America

and in the Great Antilles is directly in harmony with the east and west trend of the same phenomena upon the mainland, and we cannot escape the conclusion that they are the product of the same great orogenic revolution, the age of which was mid-Tertiary, for rocks of early and late Eocene (and Oligocene) age everywhere, as exposed along the Caribbean coast, and in the Great Antilles, are folded by these mountain-making processes, while the Pliocene and Pleistocene are more horizontally laid down against the seaward margin of the mountain masses."

It is worth noting that the great orogenic movements of this region, dating from the later part of the Miocene, are in harmony with the great disturbances which took place in several continents at about the same time. They furnish a significant commentary on the infelicity of the current grouping of the Miocene and Pliocene under the common name Neocene. Nearly everywhere outside the regions of glaciation, the Pliocene and Pleistocene are more closely associated than the Miocene and Pliocene. The above use of the term Neocene makes this *period name* cover an interval of time in the midst of which occurred one of the most profound physical revolutions to which the earth's crust has been subject. For such use of the term there is but one analogy in the nomenclature of post-Algonkian time, namely, that of the use of the term Silurian, to cover all beds between the Cambrian and Devonian, although in the midst of this division occurs the greatest break, both stratigraphic and palæontologic, in the whole Palæozoic. The other physical revolutions comparable to that which took place at the close of the Miocene mark not simply the close of periods, but of eras.

In post-Miocene time, or perhaps accompanying the orogenic movements referred to, there was epeirogenic uplift and erosion, followed by moderate subsidence, and still later by uplift of slight extent, converting the shallow margin of the sea into low-lying coast lands.

The igneous rocks of the region appear to have a wide range in age. The age of the granitic mountains of east-west trend is not known, but they seem to be mainly pre-Tertiary, and probably pre-Cretaceous. Some of them may be much older. The later igneous rocks of the region seem to date in part from the later part of the Cretaceous period. Here belong the rhyolitic tuffs of the Panama formation which is believed to be pre-Tertiary. In the early Tertiary also there was great volcanic activity, but whether the vulcanism of the

close of the Cretaceous, with its accompanying disfiguration of topography, "was continuous to the present, or alternated with long periods of quiescence, cannot be answered." Thus volcanic activity accompanied the orogenic movements of Miocene time, giving "the most cataclysmic revolution of all geologic time and place."

Summarizing the evidence touching the union of the northern and southern continents, it is said that nothing is known of their relations in the Palæozoic; that land may have been continuous between them in the early Mesozoic; that it was probably so in the Cretaceous; and that in the Tertiary period only, in later geologic time, does the connection of the oceans across tropical America seem to have been possible. For their connection, even in this period, the evidence is much less conclusive than is commonly believed. For such connection "no stratigraphic proof has been discovered," and the physical character of the Tertiary sediments seems to be distinctly against any broad union. The only evidence pointing to their connections is palæontological, and even this is meager. In a single terrane of the Eocene, five species of mollusks on the Caribbean side of the Isthmus occur also in the Tejon Eocene of California. These species are held to indicate that in the Tejon epoch there was at least a shallow communication between the oceans, and that "to this epoch alone can the date of an interoceanic connection be assigned by direct palæontological evidence. . . . . All the authentic biologic and geologic evidences are entirely opposed to the possibility of a communication between the two oceans across the Isthmus or tropical American region in Pliocene or Pleistocene time." The statement of Upham, Spencer, and others, that marine Pleistocene fossils have been found at great heights on the Isthmus, is said to be erroneous.

R. D. S.

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THE

JOURNAL OF GEOLOGY

OCTOBER–NOVEMBER, 1898

THE CLASSIFICATION OF STRATIFIED ROCKS.

The problem opened for discussion in the "Symposium on Classification, etc," in the May–June number of the Journal of Geology is much wider than the compass of the particular questions raised. It was by no means lack of interest in this problem, or in the particular questions, that led the writer to refrain from participation in the symposium. My opinion, then as now, was that the real difficulties in the case will not be solved by reaching even uniform replies to the questions; and further, the meeting which was held in September, of the International Commission on Stratigraphic Classification, which I then expected to attend, was another reason for delay in expressing an opinion till after the meeting of the commission.

Taking up the subject, where it was opened in the "Symposium," I will attempt first to give a reply to the preliminary question, raised in the introduction by the following sentence, viz.:

"Granting that these questions cannot be answered finally at present, or in the near future, it is still urgent to inquire: *By the use of what system, provisionally adopted for current use, can we best work on toward better systems in the future?*"[1] In framing a reply to this question, let me first call your attention to the steps already taken toward the construction of a provisional system of general classification and nomenclature for stratified rocks.

It will be remembered that in 1878, twenty years ago, the

[1] Jour. Geol. Vol. VI, p. 334.

first International Congress of Geologists met in Paris. The chief purpose of this congress, as set forth in the first article of its programme was, "*Le'unification des travaux géologique au point de vue de la nomenclature et du figure,*" which in English is — the attainment of uniformity in the naming, classifying and mapping of geological facts. At Paris papers were read and discussions were held, but few results were reached beyond the appointment of commissions to prepare for definite future work. At the second meeting, held in Bologna in 1881, a commission was appointed with power delegated to take the necessary steps for the making of a geological map of Europe. The discussions at this congress and at the next, held in Berlin in the year 1885, and the work of the commissions meeting at Foix in 1882, at Zurich in 1883, at Geneva in 1886 and at Manchester in 1887, all were directed toward the perfecting of a system of nomenclature, classification and cartography upon which to construct this European map. The map necessarily covered the territory of a number of independent states, whose geological surveys had been carried on independently by men speaking in several different tongues, and it was necessary to reach uniformity in nomenclature and method of representation of the facts for all these European states, in order to construct that map. Although the map was not then complete, at the time of meeting of the London Congress in 1888, the great majority of the disputed questions had been settled. In many cases the agreements were rather compromises, necessitated for the execution of a common map, than real settlement of the disputed points, or the attainment of actual uniformity in usage.

Thus the European classification and nomenclature, as set forth in the decisions of the congresses previous, it may be said, to St. Petersburg, were incident to the preparations of a geological map of Europe, and should not be regarded as constituting a universal scheme, any more than that devised for the preparation of a geological map for a similarly restricted area in another continent. Some American geologists realized this fact and, while taking deep interest in the discussions and the

expression of the views of their fellow workers, saw no reason for interference with, or the taking of an active part in, the solution of questions which pertained so largely to European geology. It was evident, to one watching the work of the congress, that the difficulties and dissent increased as the territory under consideration enlarged. England and Russia whose domains lay farthest from the center of Europe had greater difficulty in adjusting their classifications and nomenclatures to the common scheme than did the diverse states situated in the central part of Europe; and the geologists of the United States, most of all, have found insurmountable difficulties to the complete application of the European scheme to their own work. After the questions relative to the construction of the geological map of Europe were settled, this general dissatisfaction with attempts to settle questions of science by majorities resulted, at the London meeting, in the decision no longer to settle questions of general debate by formal votes; and in the following congresses, at Washington, Zurich and St. Petersburg, only such questions as had been submitted for consideration to commissions, and were carefully formulated, were put to formal vote of the body of the congress.

While these things were going on in the congress, the geologists of the United States were active along the same lines in their own country.

A few American geologists attended the Berlin Congress in 1885, and prepared a detailed English report of the proceedings. (The official proceedings of the congresses have been reported in French.) After their return an American committee, composed of fifteen geologists, set to work to prepare a report on the classification and nomenclature then in use in America. This report was submitted at, and published as a part of the proceedings of, the London Congress in 1888. In this report, the state of progress toward uniformity in the United States, of both nomenclature and classification of stratified rocks was given in summary form; and some of the difficulties and diversities in usage were pointed out. Following this, and probably suggested by one of

the chapters of the report, a Division on Correlation, as a distinct department of the survey, was organized by the Director of the United States Geological Survey. A series of bulletins were published (Nos. 80–86), in which a thorough discussion was made of the historical development of knowledge, nomenclature, and classification of each of the grand systems of the geological column on the American continent. The first "essay" was published at the time of the Washington Congress, in 1891. Two of the volumes contemplated have not been published at the present date. Each of them was prepared by a specialist and was based upon thorough study of literature and knowledge of the facts.

In this series of essays, the fact was clearly demonstrated, (which had been already announced for the Devonian in the American committee's report) that the formations of each one of the grand geological systems present such great diversity in physical features and even in the particular composition of their faunas, that two, three, and, in some cases, four distinct classifications, with as many sets of different names are needed to represent the true state of facts regarding each one as known to science at the present time, in the United States alone.

The first of this series of bulletins on correlation was issued in 1891, at the time of the meeting of the International Congress of Geologists at Washington.

While the European geologists were struggling with the various difficulties arising in the attempt to put the geological features of the various states of Europe onto a single map, with a single system of color conventions and a common legend, the United States Geological Survey was dealing with similar problems on the continent of North America. Not only was the territory covered by the work of the United States Geological Survey quite as vast as that covered by the map of Europe (the total area of Europe being 3,800,000, and that of the United States being 3,536,290), but the geology in the several states in America is found to present a greater variety of expression and more complete diversity of composition than is expressed in the states

of Europe altogether. So that the members of the United States Geological Survey, in their own legitimate work, have been obliged to consider as wide problems as have engaged the International Congress of Geologists, whose preponderating majority is made up of European members.

As early as 1881 a cartographic system was devised by the survey for the preparation of its maps. This was described in the second annual report of the survey and also was communicated to the Second International Congress meeting at Bologna in 1881. As happened to similar schemes presented by representatives of the various Europeans, this was a provisional scheme whose modification was the natural result of their comparison at the meetings of the congress, and the trials of the system in actual mapping of widely diverse problems.

In the years 1889–90 the importance of a uniform and established scheme for all the maps of the United States led to the holding of a "Conference on Map Publication," which was called by the Director of the Survey, was composed of nineteen of the most experienced and ablest geologists of the country, and was held in Washington, in January 1889,

As a result of this conference a scheme of classification and set of rules for use in mapping the results of the work of the United States Geological Survey were prepared. These rules were published in the Tenth Annual Report in 1889, and have been the basis upon which the reports and maps of the survey have been constructed since then. The scheme differs from the European scheme adopted by the International Congress in many particulars. The difference which is most striking on comparing the two, has relation to the principle of uniformity itself. The European system is built on the assumption that uniformity in nomenclature is practicable, and should be attained as far as consistent with the divergent opinions and practices of the various states concerned. The United States system is fundamentally elastic, and rests on the general assumption that uniformity is practicable only in respect to the grander divisions, and that diversity in both naming and classifying the subdivisions of

the geological systems is both practicable and necessary to the true representation of the facts in the case.

It is this fundamental characteristic of the United States scheme which furnishes the answer to the question quoted at the beginning of this article from the "Symposium" of a few months ago. The system which should be adopted provisionally for current use, both by geological workers and by teachers, must recognize this fundamental fact, that the units which it is attempted to name and classify in stratigraphical geology, are not constant units, presenting uniform characters for the whole world or for each continent, but are very inconstant, preserving the same characters for only very limited areas.

Since this is known to be the actual fact regarding geological formation, it is useless to attempt to hold to a rigid system of nomenclature, or to raise the vain hope that the use of the same names will help us over the difficulties arising from the great diversity of facts.

Having recently attended the meeting of the International "*Commission des classifications stratigraphiques*" in Berlin, it is with great pleasure that I am able to report that the commission appointed at the St. Petersburg Congress adopts this principle of elasticity in all matters of detail as a foundation principle in the construction of rules for use in discussing international stratigraphy. Professor Renevier, the chairman of the commission, has not yet published his official report of the proceedings, hence I will not attempt the discussion of details until the report is received. But I believe it will interest all American geologists to know, that several principles, which we believe in, and on account of which has arisen some of our dissatisfaction with the European nomenclature and classification adopted by the International Congress for the map of Europe, will be recommended as the basis of an international system of classification.

One of these points is the recognition that the so-called systems, or units of the second order, are the smallest divisions of the geological scale to which uniform names and position in the classification can be given in an international scheme.

A second point is that, even in the definition of these systems, a degree of elasticity must be left for the geologists of different continents and countries.

A third point is the adoption of a set of prefixes (*Paleo*, *Meso* and *Neo*) to be attached to the name of the system as a method of reaching comparative uniformity in the naming of divisions of the third order.

The fourth point is the leaving to the local geologist, the task of selecting local geographic names for the divisions of the fourth order.

Other points were discussed, but these are sufficient to show the trend of the discussions.

When the report of the commission is published, a fuller presentation of the matter will naturally occur, but until then it seems to the writer that any attempt to make a more rigid classification or nomenclature for general purposes is not to be desired.

What we all are striving for is a scheme of nomenclature and classification by which we can clearly express and represent the grander conclusions of our science which are at present so much hidden by the multitude of details. But it is necessary to bear in mind, while seeking to attain this end, that refinement or uniformity in classification, or in methods of representing the facts, will not discover the principles coördinating and determining the relations of these facts to each other. The system of our classification must be based upon the knowledge already possessed, and so long as we have not discovered the clue to the great diversity presented by stratigraphic units, we must retain all the diversity they express in our detailed descriptions of them, and wait for uniformity in respect to the lesser matters until we discover the principles upon which the diverse phenomena are bound together into a systematic whole.

It must be realized that many of these diversities, in name and relations to each other of the facts of geology, which confuse the student as his studies extend to details of the geology of other areas and other countries, are not due to different usage,

language, or understanding, but to actual diversity in the facts themselves, which only wide and profound studies in comparative historical geology can reduce to a system. When, therefore, we attempt to speak of geological events in their chronological relations, the known truth can be expressed only by an elastic use of a universal scale whose divisions are few, and whose boundaries are not precise.

HENRY SHALER WILLIAMS

NEW HAVEN, CONN.
October 28, 1898.

THE SO-CALLED CRETACEOUS DEPOSITS IN SOUTH-EASTERN MINNESOTA.

THE extent of Cretaceous formations in Minnesota has not yet been exactly determined. Small areas of the Cretaceous are known to be extant in several places and also large areas are believed to lie hidden under the drift in the western half of the state, adjacent to or continuous with the Cretaceous formations which occur in North and South Dakota and Iowa. In the region where large extent of Cretaceous is thought to exist in Minnesota, the glacial drift is very deep and the underlying formations are little, or not at all, accessible. In other regions where there is generally less drift, there is not much Cretaceous deposit. A few isolated areas only are reported to be Cretaceous-covered and these alone attest whether or not the Cretaceous deposits to the westward of Minnesota had once extended quite continuously eastward in the state to or beyond the central portions, as some geologists have thought. As far as has been ascertained, all known outcrops might well belong to local or even inland deposits. Again, whatever its extent, the Cretaceous now lies, when present, always immediately beneath the glacial drift and in this position it might presumably be found strongly eroded, and, therefore, we not only do not know the original extent of Cretaceous sedimentary deposits in Minnesota but also we cannot safely predict how much of that unknown quantity might now be extant.

The known extent of the Cretaceous in Minnesota is very small, while the sometimes estimated extent is very large. This statement may be well illustrated by reference to the final reports of the Minnesota Geological Survey, in which the maps of the several counties in volumes one and two, represent a few scattered spots of known Cretaceous, while the map of the state, in volume three, which is constructed from the same data

shows one-half the area to be probably Cretaceous, beneath the drift. Further geological investigation must of course tend to lessen this enormous difference between the known and the possible Cretaceous. During the last two summers I have had opportunity to investigate the supposed Cretaceous in southeastern Minnesota with the surprising result that the reported areas and deposits, in some instances prove to be doubtful.

In this region, there have been mapped, as mentioned, probable Cretaceous areas, covering a small spot in Goodhue county, patches in Fillmore county, and a continuous area in Steele, Dodge, Mower, Freeborn, Faribault, Blue Earth, Brown and other counties. The reported known areas are that of Goodhue county, some clays in Mower county, near Austin, and gravels near Hamilton, small pockets of clay in Blue Earth and Scott counties and certain strata in Brown and Nicollet counties.

The last named is very probably Cretaceous. Near New Ulm, Brown county, have been found fossil leaves which are described by Leo Lesqueseaux[1] and referred by him to the Dakota group. I have visited the same locality and collected some of these fossils, which are abundant only in a thin discontinuous stratum of fine sandstone. The whole bed, consisting of coarse sand with some irregularly distributed clay is 30 feet or more thick and rests upon a rotted granitoid rock, which rises 10 feet above the level of the Cottonwood River. The fossil leaves were found a few feet only above the sandstone's base, in a layer which has a concretionary-like surface, and except for its width of several feet might be called a pebble, which other smaller fossil-bearing concretionary masses in the same zone certainly appear to have been. The leaves are found therefore in a broken stratum, which, however, was, with little doubt, contemporaneously deposited and broken, so that the contained flora is indicative of the formation's age. The materials of the sandstone are imperfectly asssorted and again almost arcose in character.

Other sand and clay exposures of the same age have been des-

[1] Minn. Geol. Surv., Vol. III.

cribed from the neighborhood of New Ulm on the Minnesota River, but since they have afforded no further conclusive evidence, and since they too lie on the border or outside of what should be called southeastern Minnesota, I pass them by. Again, the supposed Cretaceous, which occurs farther down the Minnesota River valley at and below Mankato, might be passed perhaps justly with a denial that it is Cretaceous. Of course Cretaceous materials and fossils may be found in drift there and elsewhere in the state. But the beds of fine clay, containing some sand, which are on and in the Shakopee and Oneota dolomite formations, bear no fossils. They are like mere pockets of residuary clays from limestones and dolomites. They occur as white or variegated clays in the seams or in pockets or resting irregularly upon the iron-stained surfaces of the dolomites. Gravels of later age, possibly from early glacial drift, have been also described as Cretaceous, while others are possibly early Pleistocene, possibly Cretaceous. There is little or no conclusive evidence of the age of these small deposits. They need therefore no detailed description here, but a full account of them can be found in Final Report, Vol. I, p. 432; Vol. II, p. 127, Minnesota Geological Survey.

The reported Cretaceous at Austin, Mower county, is more important, because upon its character has depended the coloring of several counties on the geological map. Austin lies about 60 miles southeast of Mankato, 85 miles therefore in the same direction from New Ulm. The map coloring from Mankato to Austin depended upon the occurrence of supposed Cretaceous at Austin. Here occurs a variegated clay ranging in color from pea-green to bright red and yellow, resting upon a limestone or dolomite of Devonian age. It has not however been found in place, but is always, as far as known, involved in the glacial débris. Whatever the origin of this clay, it is now glacial drift, a Pleistocene deposit, and therefore not properly to be mapped as Cretaceous.

Regarding the question whether or not these clays were derived from Cretaceous formations, it must be said that the evi-

dence indicates strongly that they were not. For example, a large pit opened by the Austin Brick and Tile Works showed about ten feet of clay of all colors jammed together, bearing bowlders of granite, especially in the upper part, and large blocks of Devonian limestone, especially in the lower part. There is no mistaking the blocks of limestone, for they pass gradually into that which underlies in heavy strata throughout this region. The limestone blocks are blue or buff like the Devonian strata in color, though, locally, they are found in every degree of decomposition, so that in one place a complete series from fresh rock to iron concretion and red clay can be gathered. At Varco, below Austin, in quarries of the Austin Cement Works, a preglacial channel about ten feet deep in the Devonian limestone is well shown, and in it the rock surface is black stained and decomposed. Upon this surface is a somewhat disturbed, variegated clay, not in strata but coating the inclined surface. Reconstructed, the preglacial condition around Austin seems to have been simply that the Devonian limestone, blue in original color, passed upwards into buff of the same formation. This, twenty feet or more thick, was penetrated by clay-filled cracks at the top, or covered by a coating of black iron-manganese oxide, etc., from one to two inches thick ; the former condition passing to a red clay with black concretions and decomposing brownish limestone blocks ; the other phase, that of the black unbroken rock surface, as at Varco, passing simply into homogeneous residuary clay. The pea-green clay is calcareous and it was not residuary but formed strata or laminæ between the limestones. Such a clay is seen in the Devonian at Le Roy, in the southeastern part of the county,[1] and again it should not be forgotten that the Devonian at Austin extends upwards nearly to the horizon of the Rockford shales, so well developed southward in Iowa.

The identification of the clays at Austin as Cretaceous was based upon a few specimens of fossil leaves found in digging a well (*vide op. cit.* p. 354). At first the subjacent limestone was also called Cretaceous by N. H. Winchell, but this mistake was

[1] See also Geol. Surv. Minn., Vol. I, p. 357, l. 7.

soon corrected through the identification of fossils by H. S. Williams. The occurrence of a true Cretaceous fossil in this Pleistocene deposit does not prove the origin of the clays, because also pre-Cambrian rocks and Devonian fossils are scattered quite abundantly in it. The Austin clays are not Cretaceous and it is very doubtful that they ever could have been such.

Another supposed Cretaceous deposit has been described, also by N. H. Winchell in the northeastern part of Mower county. There is, in this district, a "white pebbly conglomerate which passes into a ferruginous grit." In the adjacent part of Fillmore county, the same occurs, and was identified as Cretaceous. Near Spring Valley, a few miles farther south, a blue clay is said to represent the Cretaceous. No actual outcrops were known of strata *in situ*, and one might not now refer any of these to the Cretaceous, especially since the "Austin rock" is now known to belong to a different formation. Indeed, they were so referred only with doubt by Professor Winchell. Of course, Cretaceous as well as Devonian, Ordovician, Cambrian and older rock débris might be found commingled in the Pleistocene drift.

In Goodhue county, about sixty miles northward from Austin and ninety east of New Ulm, there is another deposit consisting of interstratified clay and sand, which is described by N. H. Winchell as Cretaceous.[1] Fossil leaves have been found in the sandstone and are identified by Leo Lesquereaux as Cretaceous fossils.[2] I have verified the occurrence of the leaf imprints, though of course their identification is not questioned. The fossils belong to the same age as the strata and the latter are therefore of Cretaceous origin since the former are.

Before describing this patch of sand and clay, it may be recalled that the deposit lies beyond the limits of Wisconsin and Iowan drift in the region of loess and Kansan or pre-Kansan drift. It is in an undulating prairie bordering on the deep valleys which lead to the Mississippi valley about twelve miles

[1] Op. cit., Vol. II, p. 43.

[2] They are described in Final Rep., Vol. III, Minn. Geol. Surv.

distant toward the northeast. The Cretaceous lies on one of the higher hills of the prairie. It is covered by the loess five to ten feet thick, which also covers the Kansan eskers, the Saint Peter sandstone of the butte-like hills and, at lower levels, the Shakopee dolomite hills, and then, on the steep sides of the valleys, the Oneota dolomite and Jordan sandstone. The glacial till or gravel is spread beneath the loess, over the same Cretaceous, Ordovician and Cambrian formations. Under this drift, the dolomite formations are commonly protected by a dark-colored residuary clay, containing chert and iron concretions. Two or three miles to the westward from the Cretaceous patch, the Saint Peter sandstone is conformably overlaid by the Galena (Trenton), and upon that may once have rested the Maquoketa (Hudson) strata. Now at the particular locality where the Cretaceous patch occurs, there is neither Galena nor Maquoketa extant, but the Cretaceous rests upon the Saint Peter sandstone or possibly in part upon the Shakopee dolomite. Further, it is evident, as shown by N. H. Winchell (*op. cit.*) and others, that all the geologic formations, from the Galena down to and below the Jordan sandstone, were once, in this region at least, uniform, coextensive, sedimentary deposits, and that all the valleys are due to later erosion. This valley cutting was accomplished before the glacial deposits were spread on them. The erosion of the loess and glacial till and gravels now going on is very slight as compared to that which produced the valleys over which those deposits have since been spread.

The Cretaceous strata lie where erosion had already obtained. The Galena series, at least, must have been eroded away before Cretaceous deposit could be laid upon Saint Peter sandstone. Again, the valleys on either side of this Cretaceous, as we now see it, must be younger than such a sedimentary formation if the same is *in situ*, else the formation should lie in the valley and not on a hill. This Cretaceous patch, like the hills of Saint Peter sandstone and of other older formations in the same locality, must be the outlier or eroded remnant of a once more extensive sedimentary deposit; unless, like the bowlders of

granite, the gravels and the till, it was transported by the glacier *en masse* from the northwest.

The Cretaceous in Goodhue county is known to cover about one-half square mile from 0 to 40 feet deep. It lies in sections 3 and 10, town of Goodhue, three miles northward from Goodhue village, and one and one-half miles east of Clay Bank station. It consists of a succession of sand and clay strata which are now quite irregular, although when deposited they could not have been so. The top of the mass always shows disturbance from a glacier which has moved over it, although comparatively lightly, from a northwesterly direction. In the many pits which form a long series of exposures, no stratum appeared undisturbed, but rather every one has been shifted on the other. "The thickness of the parts varies in short distances, some of the beds tapering to points and wholly disappearing."[1]

It should be emphasized, that the irregularities of the twenty or more successively alternating sand and clay strata, are not due to sedimentation as believed heretofore, but to later dislocation which was evidently glacial. In the most regular sequence observed, which is seen in a pit on the west side of the highway, every stratum has been shifted upon the other. In other exposures they show even more irregularities, and it is quite impracticable to describe all the peculiarities of this kind. But all of them are modifications of a once regular series of alternating clay and sand strata which, as is shown by their continuity in some cases, were probably very uniform and continuous when deposited as sediment. In one case a fairly regular succession now forms a syncline. The strata dip on the one side at an angle of fifteen degrees for forty feet at least. The other side is steeper and shorter. One coarse sandstone stratum in particular runs uniformly two feet thick down one side and up the other. It could not have been so deposited. A clay stratum on the contrary is bunched into a lenticular mass in the syncline. It would not have been so deposited. Rather frequently a sand stratum is interrupted or widely isolated in thick lenticular

[1] WINCHELL, op. cit., p. 44, l. 6.

masses, then included in the clay. An exceptional case of dislocation is seen in one corner of the easternmost exposure. Here a mass of sand, eight to ten feet wide and exposed ten feet deep, interrupts the strata. Its median portion, vertically, shows obscure horizontal stratification. On the right and left, clay only, joins irregularly on the sand in large confused masses, which project in an irregular sheet two feet thick, over the same. Probably the clay extends under it. The adjacent sand strata are cut off or squeezed out abruptly by the clay, which surrounds the large sand mass. In composition this sand horse is coarser than any of the strata, but near by the same kind of coarse sand was found scattered loosely over the top, like drift. It is not ordinary glacial sand however.

Lamination is generally obscure. The clay is without lime and is decidedly tough and fine in texture. The sandstones are either nearly white and friable, or have been converted to a veritable crystallized iron ore in parts of the same stratum. It is in the dark red hard parts of the sand strata that the fossil leaf imprints occur. These parts of the strata have resisted distortion, being only here and there brecciated, so that character of stratification, like the fossils, may be clearly discerned. The rock alterations must have preceded the mechanical disturbance of the strata. Small pieces of mica further characterize the sand and coarser clays of the strata.

Excepting in the case described above, the strata are not jammed together but appear rather to have slid one on another. Even the top in contact with the glacial drift is not mixed with pebbles or bowlders, although it has been distorted to the depth of one to three feet by the glacier. The till, two feet thick or merely a thin covering of gravel, with here and there a large bowlder perched up into the loess instead of buried in the Cretaceous clay, overlies the whole mass.

What lies beneath the Cretaceous here is unfortunately not known, except in the southern part of the field, where an excavation for the railway passes through the Saint Peter sandstone. The top of exposed Saint Peter rises as high as that of

the Cretaceous. It is crusted over in one place with a black coating of iron. Upon it is found a few inches of unassorted fine sand like that of the Saint Peter sandstone, and numerous small bright pebbles, while in other places the loess rests upon it instead. On either side of the Saint Peter sandstone are Cretaceous strata which are now weathered, however, and their relation to the Saint Peter is no longer clearly defined in the exposure. But they seem to have conformed to the surface of the latter, without intervening deposit. The generally undulating arrangement of the strata in all the pits argues also that they conform to an irregular or undulating surface beneath them.

If the strata had been deposited just where they now lie, they would have been unconformable to the underlying structure, and horizontal instead of inclined. The strata have been disturbed if not transported *en masse*. Whether they have been moved a few feet or a few hundred miles remains to be shown. Likewise, one must define the mass as either in its originally deposited character, Cretaceous, or as now glacial drift. An elaborate discussion on how far rock must be moved out of location before it is to be called drift, would end in this case, however, only in the recognition of the fact that possibly some unexposed stratum may be still *in situ* as Cretaceous.

I endeavored to find some proof that this patch is an outlier of a once widespreading formation of this region. The striking presence of mica sand argues a general formation rather than a local one. In Cretaceous time, the only known source of mica must have been either granitoid rocks far to the northeast or to the northwest, or possibly the Saint Lawrence formation and Cambrian sandstones, the exposures of which could have been only far distant, while Cretaceous sediments were depositing three hundred feet above them in this region of nearly horizontal formations. Moreover I did not find that the Saint Peter sandstone detritus forms any part of this Cretaceous rock. Yet, the Saint Peter stands adjacent and protrudes to the height of the other deposit. The materials are evidently from distant sources. In the vicinity of this particular hill are other hills or

buttes which must be equally high, because they cut off the view of the more distant horizon. On these hills are farmhouses, with the never-failing wells two hundred feet deep. Excavations for cellars have also been made, but although the value of the "Clay Bank" must inevitably have been impressed upon every mind in the neighborhood, still no one is known to have observed similar clays or equivalent deposits on other hills. It is very probable that they do not exist.

In view of this contradictory evidence, other hypotheses were sought which might harmonize them. It may be suggested that either the deposit was that of a meandering river, or that the mass has been borne hither by the capricious glacier. To the former hypothesis there is the seeming objection, that the alternating strata of uniform composition and sharply defined stratification, do not suggest a river flood deposit, but it may explain the presence of mica in the sand. To the other hypothesis, however, no objection arises which cannot be circumvented.

The mass of clay and sand is large, and cannot be compared to any mass of granite or of limestone which are found among erratics; but the Galena (Trenton) shales which are tougher than limestones are known to have been transported *en masse* by the Wisconsin glaciers. Bodies of this kind are known within the city limits of St. Paul, Minnesota. One is at St. Anthony Park station, and although it is much distorted, is yet mainly unmixed with foreign materials and is highly fossiliferous, It is exposed in four places within half a square mile. At Dale and Martin streets, a similar body covering an acre and possibly a much larger area, lies in the drift high above the horizon of the shales *in situ* as exposed in the region. At Stickney, Curtice and Concord streets, a somewhat smaller mass has been cut through by the Chicago and Great Western railway, and this mass preserves the stratification quite completely although the strata form a syncline and an anticline and overlap the till. These masses, however, have necessarily been transported more than one half or one or two miles from where they were dislodged.

The Cretaceous near Goodhue is very much tougher than the

shaly clays of the Galena (Trenton) at St. Paul. The clay strata when wet would scarcely fracture under any conditions and the sand strata between them, being largely not compacted, could allow them more free movement and keep the mass from breaking apart, as long as the strata remained approximately horizontal or compressed. Moreover there is little instead of much gravel and till associated with it into which it might have been jammed by the glacier. The condition of the glacier at the time when this mass could have been dropped where it now lies, is indicated by a fine example of an esker which lies about one mile west of south, looking like one of the sandstone buttes or a dolomite swell. The esker presents an abrupt slope on its northwestern front, and extends indefinitely to the southeastward. At the foot of the esker is an exposure of Saint Peter sandstone. The brow of the hill has been excavated for a sand pit, and the strata of gravel may be seen in it dipping gently on all sides into the hill. Thin strata of nearly pure sand, unlike anything but Saint Peter sandstone, are conspicuous. The depth of the gravel is about forty feet, but the loess covering obscures the form of the hill and conceals the most of the esker deposit. A similar esker lies nearly two miles farther in the same direction, standing west of the village of Goodhue. The eskers and the Cretaceous lie in line, and notably they are perched on the brow of sandstone hills, fronting northwesterly. Again, the height of these eskers contrasts with the thinness of the till, which is only one or two feet thick, as seen in cuttings in the region. The glacier which strewed débris thinly, and which scarcely drove the residuary clays from the rock surfaces beneath it, must still have been a gigantic ice mass to have built such eskers on the farther side of a broad valley. A clay mass such as the Cretaceous here, would have been comparatively slight when once loaded upon the ice.

It is not my intention to urge this hypothesis of glacial transportation, but it is worthy of remark that the successive loose sand and tough clay strata would have been the best adapted of any to be easily slid upon the glacier, to be transported without

disruption, and to be laid down without dissolution. The peculiar rolling up of sand strata into lenticular masses between clay strata might not be easily produced by any single continued thrust of an overlying glacier, but might easily be the result of successive reverse sliding movements.

Very little, if any, attention has been paid to this Clay Bank by geologists since N. H. Winchell briefly described it, but it is not without scientific interest in its present significance, whether it is Cretaceous or Pleistocene. It has also a high commercial value. Professor Winchell believed that this clay and sand deposit might extend over several square miles and he has represented about sixteen sections on the map of Goodhue county (*op. cit.*). He has described a number of observed and reported Cretaceous exposures as occurring from two to fifteen miles distant, but none of these afford the desired evidence. Clays like that at Clay Bank might of course be expected to occur in other places in the drift and only the occurrence of strata unquestionably *in situ* can prove the same to have been deposited as Cretaceous, not as Pleistocene, in this region. There are also two other deposits which may be mistaken in this region for Cretaceous. One, the ferruginous conglomerates of the oldest drift, a sort of residuum of the oldest till, occurs here and there. No ferruginous conglomerate nor any gravels were observed in the strata of the Clay Bank, and indeed none are known to be from Cretaceous strata. A more deceptive deposit in this particular region is the variegated clays of the Shakopee formation. Such an exposure is seen one mile north of Clay Bank station in a railway cutting, where three or four feet of clay strata cover the side of a dolomite swell. When weathered, this clay remains long intact, while the dolomite strata above and beneath it are reduced. It might then be mistaken for a Cretaceous clay.

There are no Cretaceous deposits known in southeastern Minnesota which are unquestionably *in situ*, although Cretaceous clays, with fish teeth and bones or fossil leaves in sandstone, are not infrequently discovered in any of the "northwestern drift" in Minnesota. Their occurrence does not prove the proximity

of Cretaceous strata. Other supposed Cretaceous rocks are very evidently not such. With the exception perhaps of the half square mile in Goodhue county, no areas should be indicated on the map in southeastern Minnesota either as known or probable Cretaceous. At, or a little beyond, the western border of the region herein considered, the first Cretaceous begins, *i. e.*, near New Ulm.

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Minneapolis, Oct. 17, 1898.

THE SILURIAN FAUNA INTERPRETED ON THE EPICONTINENTAL BASIS.

THE oceanic movements which brought the Ordovician period to a close are believed to have been such as to affect all continents in a similar manner. The transition period from Ordovician to Silurian was probably characterized by a special shrinkage of the earth, due to an effort at adjustment to the stresses that had been accumulating during the whole of Cambrian and Ordovician time. In this shrinking process it is assumed that the ocean basins were made deeper and their capacity increased so that the waters of the shallow seas lying upon the borders of the continents and reaching into their interiors to some notable extent, were drawn off, and the bottoms of these seas became a part of the dry land. It is assumed that the continental shore lines migrated oceanward until they no longer lay upon the continental platforms themselves, but upon their abysmal slopes, and the former broad, shallow-water tracts of the sea-shelves were reduced to narrow bands. With the destruction of these shallow seas upon the continental platforms, the multitudes of shallow-water organisms which had existed in them were largely forced into extinction.[1]

After the readjustment of the solid earth, the seas began again gradually to creep upon the continental platforms by means of the landward cutting of the sea-cliffs, by reason of the sediments carried down from the land and dumped into the ocean basins, and by reason of the gradual settling back of those portions of the crust which had been locally forced upward beyond isostatic equilibrium. With the continuation of these processes new sea-shelves and new epicontinental seas came into

[1] For a fuller exposition of this hypothesis see "The Ulterior Basis of Time Divisions and the Classification of Geologic History," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 449.

existence, and grew in extent as the period advanced. These were the Silurian seas, and in them there evolved a new assemblage of shallow-water organisms, the Silurian fauna. This fauna was derived genetically from those remnants of the earlier Ordovician fauna which had happened to survive in favored localities, but with the very general expansion of the shallow waters, a great expansional evolution took place and many organic characteristics, showing a notable advance in differentiation beyond that of Ordovician time, came into existence and were characteristic of Silurian time.[1]

As the Ordovician waters were gradually drawn off from the continental platform, the once broad sea, extending from eastern Canada to beyond the present Rocky Mountains, with its wealth of organic life, was gradually contracted, and its life either gradually became extinct or was forced into modified forms or compelled to emigrate under unfavorable conditions. The remains of the last survivors, of this once magnificent fauna, within this area, are now found in the lower beds of the Medina formation in Virginia.[2] With the passing of these last survivors, the interior Medina basin became a lifeless tract so far as any evidence has been left to us, save for some low types of aquatic plants and a few worm burrows. It was probably an isolated basin.

With the encroachment of the Silurian sea upon the continent, a junction was at last effected with the Medina basin, and again marine conditions, and a marine fauna occupied the area.

The Medina fauna of New York,[3] which has been described from the upper beds of the formation, signals the return of the marine conditions. This fauna is a meager one containing but thirteen species, most of which would not be out of place in either an Ordovician or a Silurian fauna, but the presence of a

[1] See "A Systematic source of Evolution of Provincial Faunas," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 597.

[2] STEVENSON, Proc. Am. Phil. Soc., Vol. XXII, pp. 142 and 150; Vol. XXIV, pp. 85, 87 and 94.

[3] Pal. N. Y., Vol. II.

species of the brachiopod genus *Whitfieldella* stamps the fauna as of Silurian age.

In the New York section, which is usually taken as the standard for our continent, the Medina formations constitute the lowest division of the Silurian system. The Clinton division following the Medina consists in New York of a series of strata diverse in character. There are beds of shale, sandstone and limestone, and one very persistent stratum is the fossil iron ore bed. This division was well named "Protean Group" by the early New York geologists. The characters of the strata are precisely such as one would expect to find in a series of beds deposited during a period of readjustment of local conditions.

The Niagara division of the Silurian, following the Clinton, essentially represents the period when local conditions had become readjusted and equilibrium established. It was primarily a limestone-forming period, and although the Niagara shales of New York are classed with the limestone, it would perhaps be more natural from a stratigraphic point of view to place them in the preceding division.

From the point of view here taken, it will be seen that the Clinton and Niagara cannot be considered as separate and distinct time divisions having the same significance throughout the entire area in America which was originally covered by Silurian waters. The two divisions, rather, exemplify two sets of conditions. In the Mississippi valley the Clinton period of readjustment was short, and is represented by a very thin series of sediments. The conditions of equilibrium, with clear limestone-depositing seas, very soon became established after the incursion of the Silurian waters, but in New York, in the region nearer the finally established shore line, this period of readjustment occupied a much longer time. In the southern Appalachian region the Niagara conditions seem never to have been attained. Indeed, since it was probably the last region reached by the encroaching sea, it is possible that even the Clinton conditions did not begin there until long after the Niagara conditions had become established in some other parts of the continent. Taken

in a time sense, the Clinton and Niagara divisions of the Silurian must be considered as a unit, the stratigraphic distinctions between the two being of but local significance.

In like manner the Clinton and Niagara faunas must be considered as a unit. To be sure there are species which in any given area are known only in the Clinton strata, and others which are restricted to the Niagara limestones; there are also species restricted to a single stratum of either one division or the other. From the very nature of the case this would be expected, because all organisms are not so constituted as to be able to adjust themselves to all conditions of environment. There are always sure to be local adaptations in any general fauna, to the varying local conditions both in time and space. And so we must look upon the general Silurian fauna of America, not as constituted of two sharply defined faunal divisions, the Clinton and the Niagara, but as being one composite faunal unit composed of numerous faunulæ, adjusted to a great variety of local environments.

The same general Silurian fauna which occupied so large a portion of the North American continent, also was present in other parts of the world. In Europe it is recognized with its local adaptations in England, in the island of Gotland, in Russia, in Bohemia and elsewhere. Many species are common to the Silurian beds of England and North America, and there are like relations between the faunas in America and other parts of Europe. In other parts of the world this same general fauna has been found. As far away as New Zealand,[1] a Silurian fauna has been studied, in which there are several species common to Europe and North America. These facts show that there must have been intercommunication between the Silurian seas of different parts of the world, and means of intermigration for the organisms which inhabited them.

Although it has long been recognized that some means of intercommunication between Europe and the interior of North America must have existed during Silurian time, the pathway

[1] Quart. Journ Geol. Soc. Lond., Vol. XLI, p. 199 (1885).

connecting the two regions has never been definitely located. During Ordovician time there was an open passageway through the St. Lawrence valley joining the interior epicontinental sea with the ancient Atlantic Ocean, but during the Ordovico-Silurian transition period, the Taconic range of mountains was elevated, and this passage entirely closed. The Appalachian land was the eastern barrier to the interior Silurian sea, and during this period this land was joined to the Laurentian land at the north. East of this land barrier the Silurian fauna occurs in the eastern provinces of Canada, but these eastern strata are not continuous with those in New York, and the communication between the two regions was not direct.

In a southern direction the Silurian strata thin out and become more clastic in constitution, indicating proximity to a shore line, and it is probable that even at this early period the western extension of the Appalachian land, described by Griswold[1] and Branner[2] was already in existence.

The western extension of Silurian strata cannot be definitely shown, but they are nowhere a conspicuous feature in the United States further west than Iowa. Beds in the far West containing the chain coral, *Halysites*, have been referred to this period, but usually upon insufficient evidence, for this genus is known also to occur in the Ordovician. In those rare instances where other forms have been found associated with the chain coral, they usually have been of an Ordovician rather than a Silurian facies. Nowhere in the great western region has the wonderfully prolific Silurian fauna of the East been found, and it is safe to assume that the greater part of this region was above sea level during Silurian time.

This leaves the North as the only available outlet for the interior Silurian epicontinental sea. A glance at the accompanying map (Fig. 1) indicating the distribution of the Silurian outcrops in North America, shows their northward extension. There is an extensive area in the region of Lake Winnipeg (XIII), one

[1] Proc. Bost. Soc. Nat. Hist., Vol. XXVI, p. 474.

[2] Am. Jour. Sci. (4), Vol. IV, p. 357.

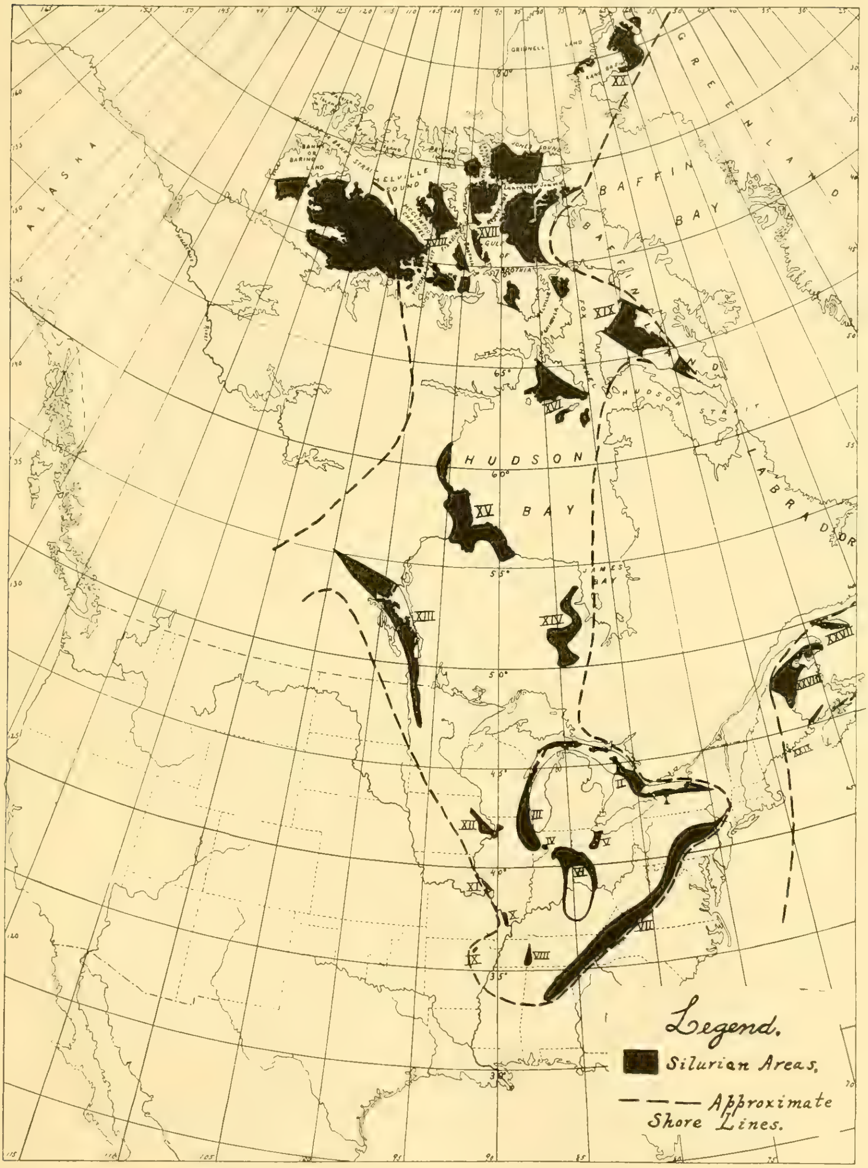

FIG. 1. Outline map of North America showing the position of Silurian outcrops and the hypothetical shore line of the Silurian epicontinental sea. The dark areas represent the Silurian outcrops, except in such instances as are specifically explained in the text.

near James Bay (XIV), and another along the western shore of Hudson Bay (XV). In all these regions the general Silurian fauna of America and Europe has been identified. The strata lie directly upon pre-Cambrian crystalline rocks, and as they could not have been deposited in these isolated patches, they must represent the remnants of a Silurian sheet which was at one time continuous and covered the entire intermediate region. Silurian strata have been recognized still further north on the islands at the mouth of Hudson Bay (XVI), and on the islands and mainland round about the Gulf of Boothia (XVII) and west of the Boothia peninsula (XVIII). In these two latter regions Silurian fossils have been found in abundance by several of the Arctic expeditions. From this general area Dawson[1] gives a list of thirteen localities from which Silurian fossils have been collected. If the region could be visited and properly studied, a prolific fauna would doubtless be secured. West of McClintook Channel the Silurian has not been properly differentiated from the Devonian, and Silurian fossils have not yet been found. In northern Greenland and in Grinnell Land (XX) Silurian strata with their characteristic fauna are known to exist.

Turning now to the map of the north polar regions (Fig. 2), it will be seen that the distance between northern Greenland (XX) and northern Russia (XXIII) where the Silurian fauna is known, is not extreme. At very near the halfway point between, lies Spitzbergen (XXI). The shores of these islands are known to consist for the most part of Palæozoic strata, and, although no Silurian rocks have yet been recorded from the islands, the presence of the Palæozoic strata is a connecting link across this little known Arctic region. In western Russia (XXIV) the Silurian strata are not exposed, but the area colored is occupied by Palæozoic strata of younger age than the Silurian, and is possibly underlain by the Silurian. The area in Russia between the regions marked (XXIII) and (XXIV) is occupied by Mesozoic strata, and the Palæozoic beds with the Silurian among them, doubtless underlie the whole region. The island of Gotland in

[1] Ann. Rep. Geol. Surv. Canada, new series, Vol. II, p. 45 R. (1887).

the Baltic (XXV) is constituted entirely of Silurian rocks, and one of the most prolific Silurian faunas known to exist in so small an area has been described from here.

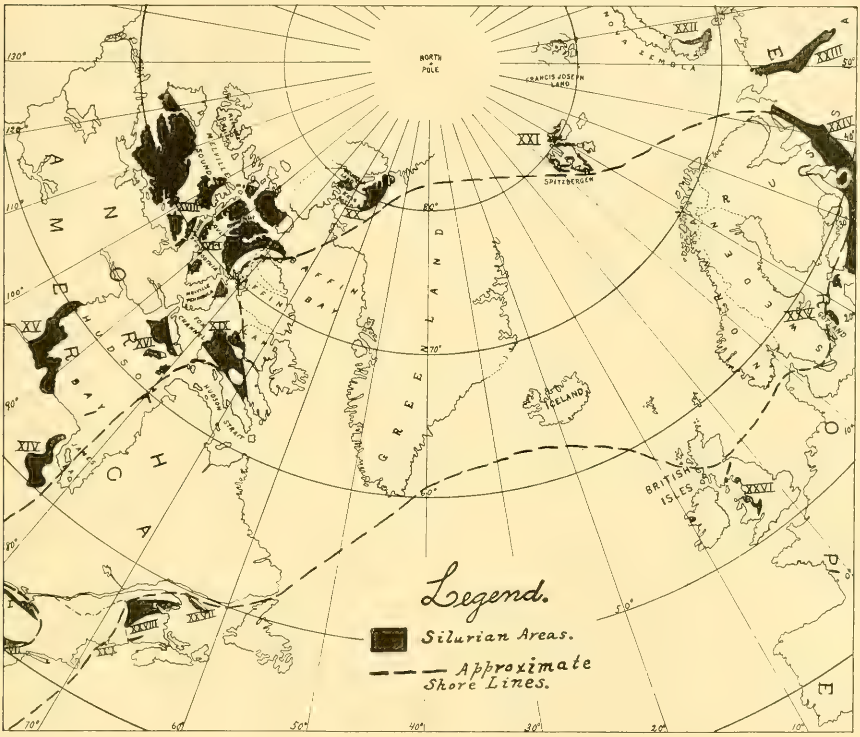

FIG. 2. Outline map of the North Polar regions with the Silurian outcrops and the hypothetical Silurian shore lines indicated.

The distributional evidence of the Silurian strata favorable to the existence of a north polar connection between the Silurian seas of Europe and those of the interior of North America having been pointed out, let us turn to the evidence of such a connection which may be afforded by the life of the period. A study of the Silurian faunas in the Mississippi valley, shows some remarkable points of resemblance with the faunas of north-

ern Europe, which are lacking in a comparison of the New York and the European Silurian faunas.

In the fauna of this age at Chicago and in northern Illinois, some remarkable forms of crinoids have been recognized which have not hitherto been recorded from America. One of these is *Crotalocrinus*, one of the most highly specialized genera of crinoids that has ever been described. Its arms, instead of being simply branched, as is usually the case, have the subdivisions joined laterally in such a manner as to form great, flat, flexible extensions from the body. It has been found most abundantly upon the island of Gotland, but it also occurs at Dudley, England, and is now found in the Chicago fauna. Two genera, *Corymbocrinus* and *Pycnosaccus*, founded upon Gotland specimens, are now found for the first time in America in the Chicago fauna. The first of these also occurs in England, but the second has been previously recognized only in Gotland.

Petalocrinus is another highly specialized crinoid genus with the arm branches from each ray consolidated into a triangular plate or "arm fan," so that the creature with its arms extended closely resembles the corolla of a flower with five petals. This peculiar genus was first described by Weller[1] from Iowa, and later a specimen was found from Indiana. The genus is now known to occur in Gotland, and several species have been described from there by Bather.[2]

Turning to the corals we find that the peculiar and highly specialized genus *Goniophyllum*, a quadrangular cup coral with an operculum of four triangular plates is found in England, Gotland and Iowa,[3] but is recognized nowhere else. The peculiar little twisted brachiopod, *Streptis*, known both from England and the continent of Europe, has more recently been recorded from the Silurian near Batesville, Ark.[4]

Now the presence of all these peculiar and highly specialized forms in various localities in the Mississippi valley and in

[1] JOUR. GEOL., Vol. IV, p. 167.

[2] Quart. Jour. Geol. Soc. Lond., Vol. LIV, p. 401.

[3] JOUR. GEOL., Vol. IV, p. 170.

[4] Am. Jour. Sci. (3), Vol. XLVIII, p. 329.

Europe, and their entire absence from New York where the fauna has really been more carefully studied than in any other part of America, is, to say the least, suggestive. If there had been a direct east and west pathway of communication between Europe and the interior of North America, why have not some of these forms also been found in New York, an intermediate locality which would have been in the direct path ?

Only a few of the more remarkable forms common to the Mississippi valley and northern Europe, but absent from New York, have been mentioned. There are many others in various classes, of a more modest and ordinary appearance, which need not be specifically mentioned here. The trilobites of the Chicago fauna, however, when properly studied, bid fair to bring out fully as remarkable points of relationship between the two faunas as the forms already mentioned.

The facts of the distribution of the life indicate clearly that northern Europe was more closely associated with the Mississippi valley than with the New York region in Silurian time. The sea-shelf connection must have been in either a southern, western, or northern direction from the interior of America. If it is shown that the Appalachian land extended westward across the southern part of the United States in Silurian time, the southern route is barred, but if that land was not present the pathway of intermigration would have been around the southern end of Appalachia and then north along its eastern shore and across to Europe. According to the mode of interpretation here adopted, it should have been, under these circumstances, along the sea-shelf of the north Atlantic, except as the species were adapted to pelagic migration, and as the Silurian strata in the eastern provinces of Canada lie in this path, some of the peculiar forms mentioned might be looked for in their fauna, but they are entirely absent so far as known. However, the stratigraphic evidence seems to shut off this southern route, because the Silurian strata grow thin in that direction and become more clastic, exhibiting every evidence of having been deposited near a shore line.

The western route need not be considered, because the Silurian fauna is not known to have any notable development in that direction. This leaves only the northern route. The presence in the Arctic localities of some of the peculiar genera already mentioned, would furnish the most substantial evidence in favor of this route. The conditions under which fossils have been collected in the Arctic regions have been such, however, that the fossil faunas of the far north are but poorly known. Although this is the fact, the genus *Crotalocrinus* has been identified from a small island in Wellington channel[1] from specimens of the stem alone. The stem of this genus, however, is quite distinctive, and the identification is probably correct. The other forms mentioned have not yet been found there, but they probably will be if the proper opportunity for the study of those faunas is ever offered.

If the interpretation here offered be the correct one, then the usual conception of the Silurian geography of North America must be somewhat altered. We must conceive of a North Polar sea with a great tongue stretching southward through Hudson Bay to about latitude 33°. There were doubtless islands standing above sea level within this great epicontinental sea, and at the latitude of New York there was a bay reaching to the eastward in which the Silurian sediments of the New York system were deposited. There may also have been a secondary tongue reaching southwestward from some point in Canada, into the Rocky Mountain region. Labrador, Greenland, and Scandinavia were in a measure joined into one great land area, though perhaps with its continuity broken, with a sea-shelf lying to the north of it and another to the south. Another epicontinental tongue of this northern sea extended south into Europe, bending to the west around the southern part of the Scandinavian land and connecting with a Silurian Atlantic Ocean. The sea-shelf to the north of the Labrador-Scandinavian land was a means of intercommunication between northern Europe and the interior of North America, and the sea-shelf to the south

[1] Quart. Jour. Geol. Soc. Lond., Vol. IX, p. 315 (1853).

of this land was a pathway between England and eastern Canada. Other tongues reaching to the south were probably present through Asia and through the Pacific Ocean, the New Zealand communication coming through one of these.

This interpretation of the Silurian, and similar interpretations of the other geologic periods, seem to call in question the generally accepted theory of the exogenous growth of the North American continent, and seem rather to point to an endogenous process of growth.

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BYSMALITHS.

A LACCOLITH as defined by Gilbert[1] is a body of igneous rock which has forced itself by intrusion, in a molten condition, between strata of sedimentary rocks in such a manner as to have lifted the overlying strata in a dome-shaped arch above it. The arching strata may be stretched and cracked to variable degrees and the molten magma may penetrate them to a greater or less extent according to the character of the rocks and the amount of cracking. A symmetrical dome may be the ideal form of a laccolith, but as Cross[2] has shown is rarely assumed because of the many modifying conditions attending the process. The principal ones are: a position of the plane of fracture along which intrusion takes place oblique to the bedding of the strata; lines of structural weakness in the strata; the presence of earlier intrusive bodies; the lack of coherence and of pronounced bedding in the strata invaded. Gilbert's use of the term laccolith embraced all lenticular bodies of igneous, intrusive rock occurring in stratified sedimentary rocks.

A laccolith is to be distinguished from an intrusive sheet of igneous rock, which also has been in most cases intruded between strata that were more or less horizontal at the time and required to be lifted by the force within the molten magma. The difference lies in the thickening of the igneous body into a more or less lenticular mass in the case of the laccolith, and in its retaining an almost uniform thickness in that of a sheet. In both cases the act of lifting the superincumbent strata must have been due to the same kind of force, namely, that exerted by a liquid under pressure upon the sides of a containing reser-

[1] GILBERT, G. K., Report on the geology of the Henry Mountains, U. S. Geog. and Geol. Surv. of the Rocky Mountain region, J. W. POWELL in charge. Washington, 1877.

[2] CROSS, W., The Laccolithic Mountain Groups of Colorado, Utah, and Arizona. 14th Ann. Rep. of the Director of the U. S. Geol. Surv., pp. 236. Washington, 1895.

voir. The difference in the results must be occasioned either by differences in the direction and rate of the intrusion, or by variations in the resistance offered by the overlying rocks. A sudden vertical thrust may lead to the arching of the strata immediately above its point of application. Local weakness of the strata may cause their elevation in particular places, as remarked by Cross. Another cause undoubtedly lies in the initial arching of strata brought about by other dynamic forces tending to bend and dislocate rocks. Such movements may be accompanied by extravasation of molten magmas which will follow planes of weakness in the dislocated rocks and will force themselves most readily where the rocks offer least resistance to displacement.

There is nothing in the petrographical characters of the rocks of intruded sheets and laccoliths in general to indicate any physical difference in the molten magmas from which each may have been formed. In both instances the magmas may have been equally liquid at the time of intrusion, or may have had similar compositions.

As regards their shape, it may also be noted that in sheets the lateral dimensions are very great in comparison with their thickness, whereas in laccoliths the thickness is much nearer the lateral dimensions.

Cross has shown that a certain amount of vertical displacement of the overlying strata may accompany their arching without changing the general character of the intruded body as in the laccolith of Mount Marcellina in West Elk Mountains, Colorado.[1] But, when vertical displacement with faulting is one of the chief characteristics of the intrusion, a distinction from normal laccolithic intrusion should be recognized. In the extreme this would result in the forcing upward of a more or less circular cone or cylinder of rock, which might be driven out at the surface of the earth, not necessarily in a coherent condition, or might be arrested at any stage of such extrusion and so might terminate in a dome of strata resembling the dome over a lacco-

[1] Loc. cit., pp. 182 and 236.

lith. By this mode of intrusion, the vertical dimension of the intruded mass becomes still greater as compared with the lateral dimensions, so that its shape is more that of a plug or core. Such an intruded plug of igneous rock may be termed a *bysmalith* (βύσμα = plug, λίθος = stone). There is then a transition from a flat, intrusive sheet to a laccolith with lenticular form, and from this to a bysmalith with much greater depth and considerable vertical displacement.

The resemblance of a bysmalith to a stock of igneous rock is such as to suggest at first their identity or close relationship. And though bodies of igneous rock may occur whose character might lead to their being classed with either of these types of intrusion, nevertheless it will be found advantageous to discriminate between bysmalith and stock by limiting the term stock to such bodies as occupy nearly vertical tubes or funnels of indefinite depth in rocks of any and all kinds, massive, schistose or stratified, and which maintain such a relation to them as to appear to belong to the category of dikes. Such tubes or funnels have been produced most probably by the enlargement of a fissure or a cluster of fissures by the carrying up of fragments torn from the walls. Stocks frequently represent the filling of a channel through which successive eruptions of magma have passed, as the conduit of a volcano. The formation of a bysmalith is more properly one act of eruption, and the solid rock removed is a block of nearly horizontal strata lifted at one time.

Examples of bysmaliths have not been described as such to any extent so far as the writer knows. Russell[1] has called attention to what he considers volcanic plugs in the region of the Blacks Hills of South Dakota and has suggested their recognition as types of intrusions different from laccoliths. But in his description of them he has mentioned nothing that demonstrates or even indicates that they possess the character of a plug. In each case they may be central remnants of small laccoliths. This is made probable by the position of the prismatic columns, which would be vertical in the central part of a laccolith, whereas

[1] RUSSELL, I. C., JOUR. GEOL., Vol. IV, p. 23.

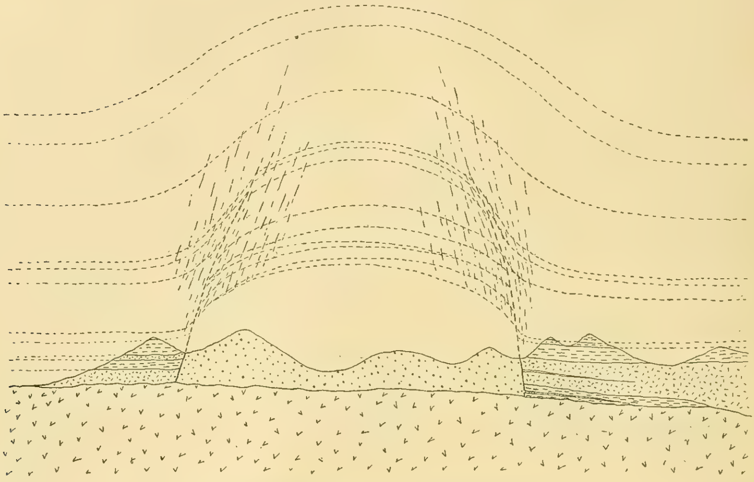
they should be horizontal in the body of a volcanic plug, and only vertical in the central part of its summit. In the case of Inyan Kara, mentioned by Russell, the dip of the limestone in the encircling wall, taken in connection with the diameter of the circle and the elevation of the igneous rock, is just what it might have been, had the igneous mass been a laccolith. The occurrences mentioned by Russell cannot be considered as illustrations of volcanic plugs without further evidence of their relations to the surrounding rocks.

In the Yellowstone National Park[1] at the southern end of the Gallatin Mountains, a great body of dacite-porphyry, three miles long and two miles wide, forms Mount Holmes and a group of mountains at the head of Indian Creek. In vertical extent the exposure of this mass is in all 2300 feet and throughout the exposure the character of the rock is so uniform as to indicate its being one mass solidified at one time.

Three quarters of the circumference of this igneous mass is in contact with stratified rocks, whose general position is nearly horizontal, but which in the immediate vicinity of the intruded body are bent abruptly upward, dipping away from it at steep angles. In several places the character of the contact plane is well shown, especially on the south side of the Dome, where a nearly vertical contact can be traced for almost a thousand feet. In each case the contact plane is almost vertical, inclining away from the intruded mass. From this mass small veins of igneous rock have penetrated the adjacent stratified rocks. The latter contained a large intruded body of andesite-porphyry in the form of a laccolith when the magma of the dacite-porphyry was intruded. The western boundary of the Holmes mass lies against gneiss and along a fault plane. An opening on this fault plane was probably the conduit through which the molten magma rose, for similar rock occurs along this fault line three miles to the north. While we have at present no knowledge of the configu-

[1] Geologic Atlas of the United States, Yellowstone National Park Folio, Areal Geology, Gallatin Sheet, Washington, 1896. See also the forthcoming monograph 32 of the U. S. Geological Survey on the Geology of the Yellowstone National Park chap. i.

ration of the bottom of the igneous mass, it seems quite probable that the magma spread in the shaly beds at the base of the Cambrian strata immediately over the nearly horizontal surface of the gneiss and beneath the laccolith already mentioned. The



Ideal section of the Holmes bysmalith.

thickening of the laccolith to the north and its contact with gneiss to the east may have hindered the further spreading of the later magma, resulting in a rupture of the overlying rocks in a block which was lifted by the intruding magma. The area of the block was more than five square miles and the vertical displacement more than 2000 feet, probably more than twice that height. Owing to the nearly uniform, crystalline character of the rock constituting the Holmes bysmalith, the grain being larger than that of the rock of the adjoining laccolith, there is little doubt that it solidified beneath a covering of strata. The slope of the planes of contact indicate that the intruded body possessed a steep dome shape, and the nearly horizontal position of the surrounding sedimentary rocks, at a little distance from the igneous body, prove that the arching of the strata took place at

a much higher horizon in the sedimentary terrane. The total thickness of beds, that were most probably superimposed on the gneiss at the time of the eruption under discussion, is about 9000 feet. These were lifted more than 2300 feet, possibly 4000 feet, and the position of the strata after the intrusion may have been similar to that shown in the accompanying figure, which corresponds in scale to the Holmes bysmalith. The section passes through Mount Holmes and Echo Peak, and does not intersect the conduit.

A more complex body of igneous rock closely related to a bysmalith occurs six miles farther north in the Gallatin Mountains at Gray Peak. It has broken across the strata and has forced into them numerous sheets of igneous rock. It is exposed at a much higher horizon than the Holmes bysmalith, cutting the Dakota conglomerate of the Cretaceous. Its position with regard to adjoining strata is not so well shown as in the case first described, however enough is exposed to prove its plug-like character.

It is probable that this type of intrusion will not be found to be as frequent as the laccolith, just as the latter is much less common than the intruded sheet.

The term *bathylith* has been proposed by Suess[1] for an intruded body having a more or less lenticular shape, which he considered to have been formed by intrusion of molten magma into a previously existing cavity made by the crumpling of the earth's crust. But, as Zirkel[2] has pointed out, the only difference between the bathylith of Suess and the laccolith of Gilbert lies in their mode of formation, their shapes being similar. It is questionable whether bathyliths defined in this strict manner exist. Indeed they probably do not. There has been a tendency among American geologists to use the term bathylith in a different sense from that in which Suess originally used it. This has been expressed by Dana[3] in his *Manual of Geology* in discussing the

[1] SUESS, E., Das Antlitz der Erde. Vienna, 1892, p. 219.

[2] ZIRKEL, F., Lehrbuch der Petrographie. Leipzig, Vol. I, p. 548.

[3] DANA, J. D., Manual of Geology, Fourth Edition, 1895, p. 811.

"granite-core" of the Sierra Nevada, California. "Such a mass of crystalline rock having irregular or indefinite outline has received the name of bathylith." This resembles the definition of stock given by Zirkel,[1] namely "stocks are irregular masses of considerable dimensions which, traversing the adjacent rocks without regard to their position, occur both in the stratified and massive terranes." However, it seems desirable to limit *stock* in the manner already suggested.

There is need for some general term that may be applied to large bodies of intruded rock whose exact character may not be evident, whose lateral extension may be quite irregular and whose depth may be profound. For such indefinite bodies the term bathylith may well be employed.

JOSEPH P. IDDINGS.

[1] Loc. cit., p. 544.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

III. REPTILIA—(*Continued*).

ICTHYOSAURIA.

The *Icthyosauria* or *Icthyopterygia* were large marine reptiles fish-like in their external appearance, with the body and limbs modified to serve the purposes of the animal in its aquatic life. The head terminated in front in a long and powerful snout armed in most cases with sharp conical teeth set in a single common groove which bordered the jaws. The skull was flattened above and the eyes were large and protected by a ring of bony plates, the sclerotic plates. The body was naked or covered with fine scales that are never preserved in the fossil forms. The vertebræ of the tail were abruptly bent downward at the extremity. This is very peculiar because in most fossil forms in which the bending of the tail occurs, the bend is upward. The external form of the tail was as in the modern fishes. There was a dorsal fin as in the fishes and the limbs were converted into paddles with a large number of phalanges.

The *Icthyosauria* were long considered as the most primitive of the reptiles because of the general appearance of the body which is so fish-like and because the paddles were considered as the direct modification of the fish fin. The bones of the upper arm and leg are so short and the carpal and the tarsal bones are so simple, being mere disks of bone, that they were regarded as the first steps from the basal segments of the fin, while the numerous phalanges were regarded as the segments of the fin rays. Now, however, there is every reason to regard the *Icthyosauria* as the specialized descendants of land-living forms.

The degeneration of the limbs and the phalanges is exactly the same as took place in the mammals that have become aquatic in their habits ; the seals, walruses and the whales.

The *Icthyosauria* are known only from the marine rocks of the Mesozoic time and chiefly from the Liassic division. Specimens are known from North America, Europe and England ; Queensland, Australia ; New Zealand and the East Indies.

Mixosaurus, from the Triassic of Besamo in Italy, is one of the oldest as well as one of the most important of the group. The animal was small, about three feet long, the head was proportionately long and there were few teeth ; the legs were long and well developed, typically those of a land-living form.

Icthyosaurus.—This genus contained a very large number of species ; it is generally divided into two groups, the *Longipinnati* and the *Latipinnati*, accordingly as the limbs, which in the whole genus have been reduced to the condition of paddles, are long and slender with few, five or less digits, or broad and short with more than five digits. Typical of the first division are: *I. quadricissus*, *I. tricissus*, *I. tenuirostris*, *I. longifrons*, etc. ; of the second group, *I. communis*, *I. trigonus*, *I. leptospondylus*, etc.

The genus is found most commonly in the rocks of the Lias. From the Wellendolomite of the Black Forest and the Muschelkalk of Crailsheim of Wurtemberg comes one of the oldest as well as one of the largest of the genus, *I. atavus*, about thirty feet long. From the Trias of Spitzbergen have been collected two species, *I. polaris* and *I. Nordenskioldi;* the first was very large, while the second was much smaller. From the Lias of England come the best preserved specimens that we have. Especially is this true of the Lyme-Regis region of Dorsetshire. *I. communis* from this region belongs to the first division, the *Latipinnati;* it was one of the largest of the genus. To the same division belong from this region : *I. intermedius* and *I. breviceps;* to the second class, among others : *I. platyodon* and *I. tenuirostris*. The first was a giant even among these large forms, but the second was quite small and delicate in structure. The paddles

had only three digits or rows of phalanges. The skull was very long and slender and the jaws were slender and curved. The whole animal was about twelve feet long.

The continental forms come almost entirely from the Upper Lias, the Poisodonomyen-Schiefer. In Germany large numbers of most excellently preserved forms are obtained from near the small towns of Boll, Holzmaden, Ohmden, etc., at the foot of the Swabian Alps, and from the neighborhood of Banz in France. Many of the forms obtained from these localities are specifically identical with the forms from the English deposits. From the Cretaceous layers of Trichinopolis in the East Indies, and from about the same horizon of the same age in New Zealand and Australia have been collected specimens of this genus. From the Island of Gozo near Malta come fragments from layers that appear to be Miocene; if this is correct, the genus extends very much farther in time than was originally supposed, but the remains are only fragments and the age of the strata is still in doubt.

Opthalmosaurus from the Upper Jurassic of England is known only from a few fragments, but is interesting from the fact that the jaws were entirely without teeth. The paddle was broad and stout with many small phalangeal bones.

Baptanodon is from the Upper Jurassic of Wyoming. This genus was also without teeth. The paddle was very broad and the phalanges very numerous.

The great geographical range, and the large number of species indicate the extensive development of these animals in the short time that they existed on the earth. That they were fierce and predaceous is amply shown by the remains of fish scales and bones that are found in the coprolites.

SAUROPTERYGIA (*Plesiosauria*).

Aquatic reptiles, generally of large size, with long necks and heads of comparatively small size; the body very short and stout, ending in a long and powerful tail; the orbits were very small and the posterior portion of the skull shows a single tem-

poral arch. The teeth were sharp and strong, conical in form and often recurved; they were set in separate sockets or alveoli. The pectoral and the pelvic girdles in the most advanced of the group were greatly expanded to serve as a protective shield for the thoracic and the abdominal regions.

The *Plesiosaurs* descended from land-living animals with well developed limbs just as the *Icthyosaurs* did. In the earliest of the *Plesiosaurs* the fore and hind legs were those of an animal that walked on the dry land at least as well as the modern alligators, but in the later and more specialized forms, the limbs are reduced to paddles which were useless for any purpose but that of swimming. The general appearance of the brute has been aptly described as that of a "turtle strung on a snake."

There are generally recognized three families of the *Plesiosaurs:*

Nothosauridæ.
Plesiosauridæ.
Pistosauridæ.

Nothosauridæ.—These were small forms that were most nearly related to the parent form of the whole group. The limbs were more or less well adapted to progression on land and there were five functional digits on each foot.

Nothosaurus, from the Triassic (Muschelkalk) of Byreuth and from other parts of Germany and from the Tyrol and the Keupfer of St. Cassian in France, was one of the small forms. It was about nine feet long. The skull was long and flat. The orbits were small and were located in the middle portion of the skull. The temporal fossa was quite large, taking up the posterior third of the skull.

The anterior nares were small and located far forward but not at the extremity of the rostrum. The teeth were numerous, small, and of nearly equal size in the posterior portion of the jaws, they formed large recurved tusks in the fore part, and were set far apart. There were 20 cervical vertebræ, 25–30 dorsals, and about the same number of caudals.

Closely related forms from the same horizon, that are known

only from fragments, are *Chonchiosaurus*, *Simosaurus* and *Lamprosaurus*.

Lariosaurus was very much smaller than *Nothosaurus*, being less than 3 feet in length. It is known from the Trias (Muschelkalk) of Italy. The skull is triangular in outline and very much shorter than the skull of the first genus. The temporal fossæ are large, the orbits and the nares small and lying quite close together. There were 20–21 cervical vertebræ, 24–26 dorsal, and about 30 caudals. There was in this genus, as in the former, a ventral armor of small abdominal ribs.

Pachypleura, from the Trias of Italy, was very similar to *Lariosaurus*, but was even smaller. It was remarkable for the length of the tail which was nearly half as long as the body. There were about forty vertebræ in the tail. The same genus is known from the Trias of Germany.

Plesiosauridæ: large forms with the limbs developed as paddles. There were five digits on each foot, but the number of phalanges is much above the normal. The whole pectoral girdle reaches a very great development in these forms so that it forms a bony protection for the thoracic region.

Plesiosaurus.—The head of this genus was small and rather elongate, the temporal fossæ were large and the orbits and nares small. The teeth were numerous in both jaws. They were long and slender, slightly recurved and set in deep alveoli. They were somewhat large at the anterior end of the snout. The neck in some of the species of the genus, was as long as the rest of the body. There were 20–72 cervical vertebræ, 20–25 dorsals, and 30–40 caudals. There was a system of abdominal ossicles consisting of a centerpiece and two or more smaller lateral pieces. The most characteristic part of the anatomy of the animal is the pectoral girdle. The coracoids became very large and the clavicles reduced to small proportions. The extension of the coracoids of the two sides causes them to meet in the median line and they together join the clavicles and the interclavicle in front, making a thick bony cuirass covering the region. The pelvis does not show such a great expansion, but there is a

considerable development of the pubis, that parallels to some extent the extension of the coracoids.

The oldest known remains of this genus come from the Rhaetic beds of England and France (Autun). The most plentiful deposit is in the Lower Lias of Lyme-Regis in England; there are about twenty-six species known from these beds, a much larger number than is known from the continent. The continental forms are found most commonly in the Lias beds in the vicinity of Holzmaden in Germany and near Banz and Autun in France.

Eretmosaurus is quite similar to *Plesiosaurus*, being distinguished only by the greater development of the thoracic shield. A headless skeleton preserved in the British Museum is about nine feet long.

Cimoliosaurus from the Cretaceous of the United States is characterized by the complete loss from the pectoral girdle of the clavicles and the interclavicle. The scapulæ and the coracoids are extended until they meet the bone of the opposite side in the median line for a long distance and join each other in a broad suture. The whole arrangement is the most specialized of any in the group, both in the loss of the two elements and in the size of the coracoids and the scapulæ. Many similar forms that show the same thing, but with slightly different shaped bones, have been described as different genera, but were all united by Seeley in the genus *Cimoliosaurus* of Leidy. These genera are *Discosaurus*, and *Brimosaurus*, from the same horizon of the Cretaceous in Alabama and New Jersey as the original genus; *Polycotylus* from the Cretaceous of Kansas (Niobrara); *Elasmosaurus*, from the same locality and horizon as the last, is of remarkable length, one specimen from near Fort Wallace in Kansas being 45 feet long, the neck alone being 22 feet and containing 72 vertebræ; *Mauisaurus*, from the Cretaceous of New Zealand.

A summary of some of the different forms referred to this genus will give some idea of the importance it attained in the latter part of the Mesozoic time.

Cimoliosaurus, Cretaceous of New Jersey and Alabama.

C. (*Polycotylus*), Cretaceous of Kansas.

C. (*Mauisaurus*), Cretaceous of New Zealand.

C. (*Elasmosaurus*), Upper Cretaceous of Kansas.

C. (*Plesiosaurus*) *helmerseni*, Gault of England and Russia.

C. (*Plesiosaurus*) *planus*, Gault of England, Russia, and France.

C. (*Plesiosaurus*) *australis*, Cretaceous of New Zealand and Australia.

C. (*Plesiosaurus*) *chilensis*, Cretaceous (?) of Chile.

The *Plesiosaurs* were powerful, free-swimming, predaceous animals that found their chief food supply in the fishes and the smaller reptiles that inhabited the same waters. The long neck and powerful teeth must have made them more than a match for any of the aquatic forms of the time, and the fish-like form and the strong paddles enabled them to get through the water with great velocity. In no other form of this time do we find such great variety of forms and such wide geographical distribution; the only region in which their remains have not been found is South Africa. A most interesting habit of the animals was the swallowing of stones, apparently to aid in the digestive work of the stomach. One specimen from the Fort Benton Cretaceous of Kansas had about 125 of these stones in the stomach, varying in size from that of the fist to that of a pea.

Thaumatosaurus, from the Jurassic (Dogger and Kimmeridge) of England and India (Gonwanda series), and also from the Jurassic of Wurtemberg, was a peculiar form with a very large head supplied with strong teeth and a very short neck. The limbs were proportionately quite long and the bones of the proximal series were better developed than common in the *Plesiosauridæ*.

Peloneustes and *Pliosaurus* are from the Cretaceous of England. The last was of gigantic size, the skull of one being over 4 feet 9 inches in length and 2 feet 11 inches across the posterior end. The neck was rather short having only about 20 rather compressed vertebræ.

Pistosauridæ: the skull, elongate and terminating in a sharp rostrum in front; the anterior nares, very small and formed by the maxillaries and the premaxillaries; the nasals, greatly reduced and taking no part in the nares; a single foramen in the palate at the anterior end, forming the posterior nares or choanæ.

Pistosaurus is the single genus; from the Muschelkalk of France and Germany.

PYTHONOMORPHA.

The *Pythonomorpha* are specialized forms of the *Lacertilian* branch developed during Cretaceous time. They were sea-living lizards, corresponding in many particulars to the popular idea of the sea serpent. They were greatly elongated in form, the limbs were specialized as paddles, and the whole body adapted to an aquatic life. They resembled the living *Varanus* or *Monitor.* The head was long and flat; the eyes, small and located far back in the skull, were supplied with sclerotic plates. The major part of the skull was formed by the long jaws, which were furnished with sharp, conical teeth, straight or slightly curved backwards, and set in separate alveoli. The upper jaw was solid and strong, with or without a rostrum extending in front of the teeth. The lower jaw was not united at the anterior end with the jaw of the opposite side, but was attached to it by cartilage, thus allowing a great degree of freedom in the action of the two jaws. Moreover, the jaw of each side was furnished with a second joint at about the middle, which allowed the jaw to be bent out or inward in a horizontal plane, and enabled the animal to swallow the large animals upon which it preyed. The brain cavity was small, and the quadrate bone was joined to the skull loosely, as in the snakes, allowing the jaws to be opened very widely. There were a great many vertebræ, giving a great length to the neck and tail as well as to the dorsal region. The vertebræ were furnished with very perfect articular surfaces, concave in front and concave behind; besides the regular arrangement for the connection of the vertebræ there were accessory articular processes such as occur in the

snakes, allowing a very great freedom of movement to the body. The limbs were modified as swimming organs. As in the case of land forms generally which have become adapted to an aquatic life, the number of the phalanges was increased, while the shape of these and of the tarsal and the carpal bones became indefinite, and, in some cases, they were even reduced to mere flattened disks of bone.

The geographical range of the *Pythonomorpha* is rather remarkable. They are known from the Upper Cretaceous rocks only, ranging from the Upper Dakota to the Lower Laramie. They have been found in the rocks of the western part of the United States, in Kansas and the Dakotas and in the Cretaceous deposits of New Jersey and Alabama; in the Maestricht beds, Lower Danian, of Belgium; in the Upper Cretaceous of England, the Chalkbeds, which are supposed to be correlated in time with the Niobrara beds of western Kansas; in Upper Cretaceous beds of unknown position on the coast of Chile and upon some of the adjacent islands, and in the same horizon in New Zealand.

The order is divided into three groups: the subfamilies *Tylosaurinæ*, *Platecarpinæ*, and *Mosasaurinæ*. Below is an abbreviated list of the characters assigned by Williston to the various divisions.

Tylosaurinæ: hind feet functionally pentadactyl; trunk short, tail proportionately long; tarsus and carpus almost wholly unossified, phalanges numerous; premaxillaries projecting as a long rostrum in front of the teeth.

Tylosaurus.—This is one of the largest of the forms. It reached in some cases, *T. dyspelor*, a length of nearly 30 feet. There were 7 cervicals, 29–30 precaudals, 80 caudals. From the Upper Cretaceous of New Zealand, Kansas, New Mexico, and New Jersey.

Hainosaurus: less well known; from the Upper Senonian of Cipley (Brown Phosphate Chalk) in France.

Platecarpinæ: hind feet functionally pentadactyl; trunk short, tail proportionately long; carpal and tarsal bones not well ossified; premaxillaries, not projecting in front of the teeth, obtuse.

Platecarpus.—This form was of intermediate size, one genus reaching a length of about 14 feet. Cervicals, 7; precaudals, 27–28; caudals about 80, probably somewhat less than in the *Tylosaurinæ.* From Kansas, Colorado, and Mississippi.

Plioplatecarpus: from the Maestricht of Belgium.

Taniwhasaurus: from the Cretaceous of New Zealand.

Mosasaurinæ: hind feet tetradactyl; carpus and tarsus fully ossified and with not more than six phalanges in each digit; trunk rather long with a shorter tail; rostrum short.

Mosasaurus: from Belgium, England, New Jersey, Dakota, Alabama, and North Carolina. Specimens from New Jersey show a length of 32–36 feet, and some of the European forms were as long as 40 feet.

Clidastes.—This was one of the smallest of the genera. *C. pumilus* was only about 6 feet long, and no species was over 12–14. Cervicals, 7; precaudals, 42; and caudals, 70. From Kansas, Colorado, New Jersey, Mississippi, and Alabama.

Many less well-known genera have been described from the rocks of this country and Europe, showing that the group had a considerable development while it lasted.

Speaking of the group, Williston says: "The food of the Mosasaurs must have consisted chiefly of fishes of moderate size with occasional victims of their own kind. While the flexibility and loose union of the jaws undoubtedly permitted animals of considerable size to be swallowed, the structure of the thoracic girdle would not have permitted any such feats of deglutition as the *Python* and *Boa* are capable of. The animals must have been practically helpless on land. They were not sufficiently serpentine to move about without the aid of limbs, and these were not at all fitted for land locomotion. They lived in the open sea, often remote from the shores. Their pugnacity is amply indicated by the many scars and injuries they received, probably from their own kind."

PTEROSAURIA.

The *Pterosauria* or *Pterodactyls*, as they are more popularly called, were reptiles that were adapted to a flying or soaring life

in the air. Just as the preceding groups, the *Icthyosaurs* and the *Plesiosaurs* had been compelled by the great struggle between the large number of reptilian forms to seek some peculiar modes of life to maintain an existence and had taken to the water, so these forms had been compelled to seek new environment and became adapted to an aërial, or partially aërial, life. Whether they were possessed of any great power of flight or were only capable of soaring, as the flying-squirrel, is not known, but the enormous distance that their remains are found from what must have been the land at the time and the pneumaticity of their bones speak for a very well developed power of flight. There was great variation in the sizes of the animals, some being very small, while others reached a spread of 18 feet from tip to tip of the expanded wings. The bones were all hollow and provided with foramina at the extremities that seem to have filled the same function that the foramina in the bones of the birds do, that of supplying air to the interior of the bones. These two facts seem to imply that the Pterodactyls were warm-blooded, but this can not, of course be definitely settled from the skeleton. The tail was either long or short. In the cases where it was long, it ended in an expansion that served as a rudder to guide the flight of the animal. The fore limbs were very much longer than the hind limbs and were especially modified to support the organ of flight. This was a strong membrane much like that which serves the same purpose in the bats. In certain of the specimens preserved in the fine grained slates of the Solenhofen beds, the folds of the wings are preserved and even the course of the nutrient arteries may be followed. There were four digits on the front foot or wing, the last four, and the last of these, or the little finger, was enormously extended so that it was many times the length of the arm. The other fingers were short and greatly reduced in size; they ended in small claws which perhaps aided the animal to cling to the sides of the cliffs on which it lived. The wing membrane stretched from this extended finger and the arm to the weak posterior limbs. In all probability the membrane extended also between the

hind legs and for a short distance out upon the tail. The head was very bird-like, all the bones being closely united and the sutures between them disappearing early in the life of the animal. The skull was of many different forms in the different species and the jaws were almost always furnished with teeth, but in some of the more specialized of the genera these were absent.

The group is generally divided into three families:

Pterodactylidæ.
Rhamphorynchidæ.
Pteranodontidæ.

Pterodactylidæ: forms with short tails; the skull quite long and furnished with teeth; the sides of the skull anterior to the orbits broken by vacuities that possibly aided in lightening the weight of the skull. The orbits were large and there was only one temporal arch. The metacarpals were longer than one half of the length of the forearm.

Pterodactylus was about a foot long and very slender in all of its proportions. The skull was long and bird-like and furnished with teeth at the anterior ends of the jaws only. There are many species of this genus known, the most of which come from the Upper Jurassic layers (Lithographic slates) of Germany, near Eichstat and Bayern. A few specimens have been taken from the Upper Jurassic of France in the department of Ain and the Kimmeridge clays of England have furnished isolated bones of the same genus.

Rhamphorynchidæ: forms with long tails which are frequently accompanied by ossified tendons; the skull only moderately elongate; the jaws furnished with teeth throughout their whole length which grew smaller towards the posterior part of the jaw, those in front being long and slender. Metacarpals shorter than the half of the forearm. The fifth toe of the hind foot taking some part in the support of the wing membrane and showing a much greater development than the other toes.

Dimorphodon, from the Lias of Lyme-Regis in Dorsetshire, England, was a much stouter form than the *Pterodactylus;* the

head was short and high with strong teeth and small lateral vacuities. The whole animal had a length of nearly three feet.

Rhamphorynchus had a rather long snout, edentulous at the anterior end in both the upper and the lower jaws. The remaining portions of the jaws were filled up with rather long and slender teeth which were directed forward. The teeth were of different sizes in the jaws, but, in general, the largest were in the anterior part. The neck was short and strong and the cervical vertebræ very short. The sternum was broad and furnished with a median keel for the attachment of strong muscles as in the modern flying birds. The tail was long with 30–36 vertebræ and strengthened by tendons. The wing of this form was more slender than in the majority of the *Pterodactyls* and resembled that of the night hawk or goatsucker. The genus is known from the Upper Jurassic (Lithographic Slates) of Bayern and Wurtemberg.

Scaphognathus was much like the preceding, except that the teeth extended to the extremities of the jaws and were few in number. They were directed vertically instead of forward. Specimens of this genus are known from the Upper Jurassic of Germany and of England.

Ornithochierus is the name given to a very large form that is known from numerous fragments in the Jurassic deposits of England. The jaws seem to have been furnished rather sparsely with teeth of considerable size which extended to the extremity of the jaws. There are a great many species represented in the rocks of England from the Wealden to the Cretaceous, in all about 25. One form from the Chalk, *O. giganteus*, must have possessed a spread of wing of about 15–18 feet.

Pteranodontidæ: the skull long and terminating in sharp, edentulous jaws; no lateral vacuities in the skull; the tail, short.

Ornithostoma was originally described from the fragment of a jaw from the Chalk of England, but no more of it was known than that it was without teeth.

Pteranodon (?), from the Upper Niobrara, Cretaceous of Kansas, was a very large form with toothless jaws; probably

synonymous with *Ornithostoma.* Head much elongate; the jaws slender, pointed and wholly wanting teeth; external nares and antorbital vacuities united; supratemporal fossa of large size; occipital crest elongated; the anterior dorsal vertebræ united and bearing a supraneural plate for articulation with the scapulæ; tail short and small; four functional toes on the hind foot.

Speaking of the general appearance of the animal, Dr. Williston says: "Altogether the skeleton of *Ornithostoma* presents some remarkable characters. I believe there is no other reptile in which the prosthenic features are carried to as high a degree as in this. The disproportion between the fore and hind extremities is almost ludicrous. The pelvis is exceedingly small, the legs not only small but weak in all respects. That the animal could have stood on its feet free on the ground I do not believe possible. The neck vertebræ are relatively stout, but the neck was not remarkably elongated, to carry such a head as the animal possessed. Furthermore, the remarkable mode of articulation of the neck and the anterior dorsal vertebræ seem to indicate a restricted range of torsion, though tolerably wide sagittal flexion. The occurrence of the remains of the large species in strata evidently formed remote from the shore lines, as shown by the absence of other animals, turtles, etc., indicates great powers of flight. Furthermore, it is rare that a single bone of a *Pterodactyl* is found unassociated with others, and almost invariably the wing bones are found more or less in connection, indicating either tough and horny tendons or a rapid sinking in the water, which might happen from the filling of the hollow bones with water through their pneumatic openings.

"Notwithstanding the enormous expanse of the wings, I do not think these animals could have weighed much when alive. I doubt very much if one of the largest species reached twenty pounds."

Nyctodactylus was a form from the Cretaceous of Kansas (Niobrara) that differed from the previous genus principally in the size, the wings measuring less than ten feet when expanded. The jaws were almost certainly edentulous.

TESTUDINATA.

The turtles may be briefly described as reptiles that have lost the teeth completely, and have developed an external skeleton in the shape of a bony case that is more or less complete and protects the body of the animal. There is little doubt that they are derived from animals that did not possess such a structure, but the point of their divergence from the primitive stem is so ancient that it has not yet been detected, and the oldest form that we know is a member of the most specialized group of the turtles.

The order is generally divided into three suborders:

Trionychia.
Pleurodira.
Cryptodira.

The *Tryonichia* differ from the typical forms of the *Testudinata* in that the bony exoskeleton is largely represented by a thick, leathery skin, which has given them the name of Soft-shell Turtles. Beneath this skin is developed a series of small bony plates with a characteristic sculpture, that in many places form the chief remains of the forms.

Trionyx is the most common of the extinct forms. The oldest remains are from the Upper Cretaceous of New Jersey; these are, for the most part, fragmentary remains of the plates of the carapace. From the Upper Cretaceous, Laramie, of the western part of the United States and British America, have been collected a large number of specimens. Through all the deposits of Tertiary age in Europe, specimens of this genus have been found; in the United States it is found throughout the Tertiary of the eastern part, but in the west seems to be confined to the lower layer, the Eocene. Remains of still living species have been found in the Pleistocene beds of India and Burmah.

The *Cryptodira* are by far the most important group of the Testudinata, both in number of species and their distribution in time. The group is characterized by the fact that the pelvic bones are not anchylosed to the carapace and the plastron above and below. There were developed so many forms that it is

impossible to consider more than a few of the genera. There seems to be a division of the group in very early times into land-living and water-living forms. The first of these gave rise to the common swamp and land turtles of today, and the second group to the sea turtles, the *Pinnata*.

The second of these groups may be considered first; *Dermochelys* is the most specialized of the genera. This is a gigantic form still living in all of the oceans, though little known from its almost exclusively pelagic habits. The carapace has entirely disappeared and is replaced by a tough leathery skin that has won for them the name of "Trunk-backs or leather-turtles." The plastron is less completely removed but there is a large space in the center, between the bones called the fontanelle. The fore limbs are developed as flippers, the anterior pair being much the longest.

The more common members of the same division are the Loggerhead and Green turtles. In these the carapace and plastron are less reduced, but both show large vacuities that indicate the steps by which the condition in *Dermochelys* was produced.

Protostega is the earliest of the definitely known forms. It is from the Upper Cretaceous (Niobrara) of Kansas. Similar in many respects to the recent *Dermochelys*, it still shows many primitive characters that indicate its separate position. The carapace was not ossified, but the proximal ends of the ribs show lateral expansions that would, if carried a little farther, produce the condition found in the *Chelonia* (the most primitive of the living sea turtles). The genus was one of the largest of the order. One specimen measured nearly or quite seven feet in length.

Protosphargis, from the Upper Cretaceous of Italy, *Eosphargis*, from the London Clay (Eocene), and *Psephophorous*, from the Miocene of Germany, are all closely related to *Protostega* and show successive steps toward the condition of *Dermochelys*. The great geographical extent of these forms seems to indicate that they possessed the same roving and pelagic habits that characterize their nearest living relative.

Remains of the closely related forms that culminated in the Cheloniidæ (*Chelonia*, etc.) and differed from the previous forms only in the more complete carapace, are found in the Cretaceous of Europe and America. These forms show characters of the land turtles as well as of the sea turtles, and are in all probability the forms that represent the branching of the primitive stem of the turtles. Such forms are *Propleura*, from the Cretaceous of New Jersey, *Osteopogys*, from the same locality, *Toxochelys*, from the Niobrara, Cretaceous, of Kansas, and *Euclastes* from the Cretaceous of New Jersey, the Greensand of Cambridge, England, the Eocene of England and France. Forms more common on the continent are *Eurysternum*, from the Upper Jurassic of Germany, *Idiochelys*, from the same horizon in France (Cerin) and Germany (Kelheim). *Hydropelta* is quite frequently found associated with the remains of *Idiochelys*.

Of the common swamp and land turtles more is known than of the sea turtles. The ancestors of the *Chelydridæ*, or common snapping turtles, are found as far back as the Upper Jurassic. *Platychelys* from this horizon, at Kelheim, is one of the typical forms. In *Platychelys* there was an extra pair of plates in the plastron, the mesoplastra, that did not reach the middle line from the sides.

Helochelys, from the Greensand (Cenomanian) of Kelheim, was quite similar to the preceding. The whole surface of the carapace was covered with wart-like projections, except the lines that marked the union of the horny plates with the bony ones beneath. In this form the mesoplastron was narrow but complete, and extended from each side, meeting in the middle line. It was quite large, about a foot and a half long.

Compsemys is a very large form, distinguished by the fact that the plates of the carapace are joined by suture to the peripherals, and are marked by small pit-like excavations. It is very plentiful in the Upper Cretaceous layers (Fort Union and Laramie) of the western part of this country.

Anostira was a small form from the Lowest Eocene (Bridger) in Wyoming.

Apholidomys and *Pseudotrionyx* are from the Eocene of France. The true land turtles, *Testudo*, mostly, are characterized by the great elevation of the carapace and the smoothness of its bones. The claws of the toes are in many cases shortened till they appear as broad nails. The earliest forms known are from the Eocene of Wyoming and New Mexico, the Wasatch and Bridger. In Europe the earliest forms occur in the Oligocene. Throughout the Miocene and the Pliocene layers of both the old and the new world, the genus abounds. The best region for the remains, however, is the Bad Lands of South Dakota, Miocene or Oligocene, where they occur in great abundance.

Especially remarkable was the gigantic *Collosochelys* of the Siwalik Hills of India (fresh-water Miocene). The animal was fully 18–20 feet long, the carapace alone being 12 feet long and 8 feet high.

From the Pleistocene of Queensland, Australia, comes the peculiar form *Meiolania*, which possessed horns or bony protuberances on the skull.

During Pleistocene times many of the islands of the East Indies were inhabited by enormous land turtles. Remains of such are known from Mauritius and Rodrigues. Similar remains are known from the Island of Malta and on the Galapagos Islands off the coast of Central America there are still living forms of the same group.

The *Pleurodira* are the forms in which the bones of the pelvis are joined by sutural union to the bones of the carapace and plastron above and below. They are few in number in recent times, and were little if any more numerous in past time, though, peculiarly enough, the most ancient turtle known is a member of this suborder. *Proganochelys*, from the Upper Triassic (Keupfersandstein) of Germany, *Plesiochelys*, from the Upper Jurassic of England, and *Bothremys*, of the New Jersey Cretaceous, are also members of the same group.

PROGANOSAURIA.

These forms are of the greatest interest from a phylogenetic standpoint. They are generally regarded as the most primitive

form of the reptiles, and from them are probably derived the majority of the reptilian orders. They are characterized by a very generalized structure of the skull and skeleton that in many regards closely approximates the condition of the *Amphibia*. The bones were not completely ossified; there were many abdominal ossicles, and the vertebræ were perforated for the passage of the notochord. The group is extinct.

Paleohatteria, the earliest of the order, is found in the Rothliegende, Upper Permian, deposits of Niederhasslich near Dresden. It was a small lizard-like animal about a foot long; the teeth were small and conical, and were developed on the vomer and palatine bones of the mouth as well as in the jaws, a character common in the *Amphibia*.

Proterosaurus is another form much longer and more slender, about six feet in length. It is peculiar in the fact that the vertebræ of the neck are only seven in number, and are greatly elongated, as is common in the long-necked mammals. It is from the Keupferschiefer of Thuringia.

Mesosaurus, from the Permian or Permo-Triassic of South Africa, is represented by the impression of the anterior half of an animal that was much like the Plesiosaurs in general appearance; the neck was long and slender, and the head had the same kind of teeth. The posterior portion of an animal that is regared as belonging to the same genus has been found in the Permian of Brazil.

RHYNCHOCEPHALIA.

The members of this order differ only in degree from the preceding. The bones are better ossified; the abdominal ossicles are reduced in number and simplified in arrangement; the notochordal opening in the vertebræ is smaller and the skull has advanced toward the modern type of the reptiles. The group is of great importance, both because of the variety of the forms produced and because it is in all probability the direct ancestor of the later reptiles. The living *Lacertilia* and *Ophidia*, and, in all probability, the *Testudinata*, as well as the extinct *Plesiosaurs*, *Icthyosaurs*, *Pythonomorpha*, *Pterosauria*, *Dinosaurs*, *Croco-*

dilia, and possibly the *Theriodonta* must be regarded as the descendants of this order. Through the *Dinosaurs* the Birds are related to the order, and through the *Theriodonta* the Mammals.

Rhynchosaurus and *Hyperodapedon* are two forms from the Triassic, Elgin Sandstones of Scotland and the Triassic beds of Warwickshire in England. The latter genus has also been described from the Maleri, Triassic, beds of the East Indies. They were small forms, quite similar in external appearance to the modern lizard, except that the incisor teeth of the jaws were developed as great curved processes. The roof of the mouth was covered with teeth, and there was a single external nostril.

Homœosaurus and *Sapheosaurus* are from the Upper Jurassic of Germany and France, notably the Lithographic Slates of Kelheim. They were very similar to the modern lizards in appearance.

Sauranodon, from the Jurassic of Cerin in France, was similar to the foregoing, except that the jaws were greatly extended and were edentulous.

Champsosaurus, from the Upper Cretaceous, Laramie of Wyoming, and the lowest Eocene, Puerco of New Mexico, and *Simœdosaurus*, from the Eocene of France and Belgium, are very peculiar in that the articular faces of the vertebræ are nearly flat, instead of being deeply concave, or even perforated, as in the majority of the *Rhynchocephalia*. It has been suggested that the two forms are identical, but as the skull of *Champsosaurus* is not known it is impossible to settle the question. The skull of *Simœdosaurus* was long and slender, with an anterior rostrum much like that of the modern Gavial of the Indian rivers.

Sphenodon, from New Zealand, is the single living member of the order. It probably appeared in the Jurassic, though it is still unknown in the fossil state.

The modern *Lacertilia* and *Ophidia* are the direct descendants of the *Rhynchocephalia*. The chief differences are the loss of the lower one of the temporal arches (in some cases of both) and the loss of the abdominal ossicles. Moreover, the deeply biconcave character of the vertebræ, amounting in most cases to a

perforation of the centrum, is absent in most of the *Lacertilia* and all of the *Ophidia*. The loss of the limbs in the snake is but a secondary character, and is nearly accomplished in many genera of the lizards.

The earliest of the *Lacertilia* is from the Isle of Purbeck in Dorsetshire, England. All that is known of the specimen are the imperfectly preserved remains of the skull and some of the scales. The genus is called *Macellodon*.

Hydrosaurus, from the Lower Cretaceous of the Island of Lesina in the Mediterranean, was very similar in appearance to the modern monitors. (This genus was the direct ancestor of the great, specialized group of the *Pythonomorpha* developed during the Cretaceous.)

Dolichosaurus and *Coniosaurus*, from the Upper Cretaceous of England, and *Tylosteus*, from the Cretaceous of North America, are typical lacertilians. The Tertiary rocks of both hemispheres abound in the remains of the *Lacertilia*. The development of these forms began so early that even in the earliest Eocene we find representatives of the families and even of the genera of today. Zittel in his *Handbuch* enumerates from the Eocene of Wyoming the remains of *Chameleo*, *Iguanavus*, *Glyptosaurus*, *Saniva*, *Xestops*, *Thinosaurus*, and *Tinosaurus;* from the Eocene Phosphorite (Upper Eocene) of Quercy, *Agama*, several genera of the *Iguanidæ*, *Paleovaranus*, and *Lacerta*.

In the Miocene deposits of Europe are found many of the existing genera. In the Miocene of the western states, especially Colorado, are found such genera as *Exostinos*, *Aciprion*, *Diacium*, *Platyrachis*, and *Crematosaurus*.

Most of the remains of the Pliocene and the Pleistocene formations belong to existing genera and species, with the exception of the Australian *Megalania* and *Notiosaurus*.

The *Ophidia* are very poorly known from the fossil forms. The only parts preserved are the vertebræ. With the single exception of *Symoliophis*, from the Cretaceous of Charente, the known fossils are from the Tertiary layers. From the London Clay (Eocene) and the Eocene sand of France come the remains of

large Python-like forms. The Eocene of New Jersey has yielded one form, *Titanophis*, and the Puerco of New Mexico *Helegras*. The Eocene of Wyoming has yielded *Boavus*, *Lithophis*, and *Limnophis*.

The Miocene layers of both this country and Europe have afforded many scattered fragments that belong mostly to living families. The Pliocene and the Pleistocene contain only genera and species of living forms.

CROCODILIA.

The *Crocodilia* are lizard-like forms of generally, large size possessing many characters that indicate their origin from the *Dinosaurs* and the *Rhynchocephalia*. The tail is long and powerful, the jaws armed with strong, simple teeth, the skull flattened, and the anterior end produced into a rostrum of varying length; there is generally developed in the skin a series of bony plates that in some forms is confined to the back, and in others extends to the skin of the abdomen as well; there are generally developed abdominal ribs in the body wall.

The order is divided by Zittel into three suborders:

Parasuchia.
Pseudosuchia.
Eusuchia.

The *Parasuchia* are the nearest of all the order to the ancestral stem of the *Crocodilia*. The possession of paired anterior nares, located far back on the upper surface of the skull, of large preorbital openings in the skull; the structure of the base of the skull and the palatal region, and the structure of the shoulder girdle are all characters that unite the suborder with *Dinosaurs* and the *Rhynchocephalia*.

Belodon, the most common form, was about nine feet long; the skull extended forward in a long, high, and laterally compressed rostrum; the jaws were filled with strong, simple teeth; there were two rows of plates extending down the middle of the back, and others less regularly developed in the skin of the sides; the limbs were weak and probably had about the same

proportions as in the modern Crocodile. Remains of the genus are known from the Trias of Germany, and from the same horizon in both the eastern and western parts of the United States.

Stagonolepis and *Parasuchus* are forms separated from the foregoing by minor characters of the skull and teeth. The first is known from the Triassic (?) Elgin Sandstones of Scotland, and the latter from the same horizon, Maleri Sandstone of the East Indies.

Pseudosuchia.—These are very peculiar forms from the Triassic rocks; the genera were all small, not over a foot long at the outside; the most characteristic thing about them was the development of a cuirass of bony plates in the skin, that protected every part of the body from the head to the tail, and included the ventral as well as the dorsal side of the body.

Ætosaurus, from the vicinity of Stuttgart in Germany, is the best known form. A single slab in the Stuttgart Museum has the remains of twenty-four individuals preserved in it.

Typothorax is the name given to a form described by Cope from fragments of the ribs and the dermal plates discovered in the Triassic rocks of New Mexico.

Eusuchia.—This suborder is in general characterized by the shortness of the premaxillaries and the location of the external nares far forward on the snout; the roofing over of the palatal portion of the mouth by the gradual extension inward of the palatine and maxillary bones, and the crowding of the internal nares back toward the posterior part of the mouth. There are two sections described, the *Longirostres* and the *Brevirostres;* the first possesses a long, slender rostrum formed by the extension of the maxillary bones; the anterior nares are not divided at the anterior extremity, and the teeth are little differentiated. The *Brevirostres* have a short snout, with the anterior nares divided, and the teeth more or less differentiated.

The *Longirostres* contain several families, typical of which are the *Teleosauridæ* and the *Gavialidæ*. The *Teleosauridæ* are the oldest known of the *Eusuchia*, specimens being known from the Lias. The oldest of the forms were marine, and the latter

inhabited fresh water. They were powerful swimmers, with much better developed limbs than the modern Crocodiles. The skin of both the back and abdomen was strengthened by the presence of bony plates that formed a very perfect armor. Prominent forms were *Pelagosaurus* from the Upper Lias of Germany and France; *Mystriosaurus*, from the same horizon in Germany; *Steneosaurus*, from the Upper Jurassic of England and the continent; *Teleosaurus*, from the same horizon and localities, etc. Many genera are known from layers younger than the Jurassic, and these seem to lead naturally to the *Gavialidæ*, which are known from the late Tertiary of India, and are found living in the rivers of that country.

The *Brevirostres* became prominent in the Upper Jurassic, and occupied a very important part in the later times. Of five families described two are still living.

Alligatorellus was a small form from the Upper Jurassic of France; it was less than a foot long, and was characterized by the possession of biconcave vertebræ.

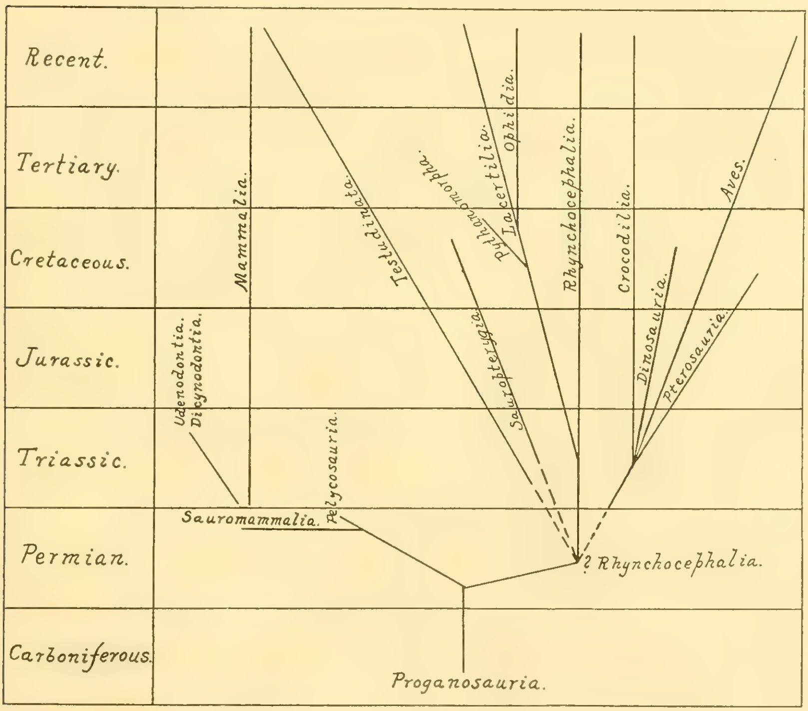
Goniopholis, from the Upper Jurassic of England and the continent, was a much larger form than the preceding. It possessed biconcave vertebræ; there was a double line of dermal plates in the skin of the back, and the ventral surface of the body was protected by a large number of plates joined by suture. Similar forms have been described by Cope and Marsh, from the Jura of the Rocky Mountains, under the names *Amphicotylus* and *Diplosaurus*. These may be synonymous with *Goniopholis*.

Bernissartia is from the celebrated fossil region near Bernissart in Belgium. It is characterized by the fact that the teeth are differentiated into separate sizes in the jaws. *Theriosuchus*, from the Purbeck of England, is regarded as belonging to the same family.

The true Alligators and Crocodiles appeared in the fresh water deposits of the Cretaceous and extended to the present time. *Diplocynodon* is one of the earliest of the true Alligators. Remains are found in the deposits of both Europe and North America.

The genus *Crocodilus* appeared in the Cretaceous of France. Remains are known from the Tertiary deposits of both the old and the new worlds as late as Pliocene time, when they seem to have disappeared from all regions except those in which they are still found, tropical Africa, South America, and the East Indies.

The connection between the various groups of reptiles may be seen from the following table, which is slightly modified from one published by Baur.



E. C. Case.

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EDITORIAL.

ASTRONOMERS are not alone in appreciating the interest which attaches to the newly discovered planet DQ. Its peculiarities promise to be suggestive at least in respect to questions of planetary origin in which geologists are concerned almost equally with astronomers. The new planet breaks across that rather forcefully deduced law of symmetry which has been thought to prevail throughout the solar system and which has been somewhat too influential perhaps in controlling hypotheses of its origin. The little stranger pays no respect to Bode's law, and is eccentric in other particulars. Its mean position lies between the earth and Mars, and its period of revolution is 645 days, while that of Mars is 687. Its orbit, however, is so eccentric that in aphelion the planet's path lies far outside of the Martian orbit in the zone of the asteroids, while in perihelion it passes within fourteen million miles of the earth, according to the provisional computations made from the earlier observations. One of the most interesting features of the new planet lies in the fact that its velocity at perihelion is greater than that of the earth, although it is farther from the sun. Should the two orbits be brought into coincidence by a suitable perturbation and a collision ensue, the velocity of the outer body would be the greater, at the moment of collision, though on the average it would necessarily be less. The effect of such a collision on the rotation of the earth would depend upon the particular point at which the stroke of the smaller planet was dealt. The probabilities, however, are in favor of a stroke which would accelerate the present *direct* rotation of the earth, or which would, if the earth had no rotation, impart to it a rotation in the same direction as that which it now possesses. It has been urged that meteoroidal bodies revolving in a ring around the sun would, on

union by collision, give rise to *retrograde* rotations, because the orbital velocities of the inner bodies are the greater, and this has been regarded as a serious objection to the aggregation of the earth and all but the outermost planets from a ring of discrete matter of the type of the Saturnian rings as distinguished from an aggregation from a gaseous ring after the manner of the Laplacean hypothesis. (Faye, *Sur l'Origine du Monde*, 1896, pp. 165, 270–281). The writer has, however, pointed out that, if the aggregation of such discrete matter took place through the development of eccentric orbits which cut each other's paths and thus led to collision, the bodies pursuing the outer orbits would be moving faster *at the points of collision* than those pursuing the inner orbits, and that on the average the rotations resulting from the collisions would be direct (A group of Hypotheses Bearing on Climatic Changes, JOURNAL OF GEOLOGY, Vol. V, No. 7, 1897, p. 668). The new planet furnishes us with a concrete illustration of the principle urged. It has been estimated that, at the time of its greatest approximation, the new planet will be moving 500 feet per second faster than the earth, a figure which is doubtless subject to considerable correction from fuller data. The discovery of this rather erratic body has renewed the previous suggestion that small planetoids may not be rare in other tracts than the asteroidal belt between Mars and Jupiter. It will doubtless have some influence in reopening for renewed consideration the mode of aggregation and the past history of the solar system, a consideration which has been rendered opportune by the serious, if not fatal, objections to the accepted gaseous hypothesis which have arisen from the application of the kinetic theory of gases.

T. C. C.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

Van Hise,[2] Bayley, and Smyth map and describe[3] the geology of the Marquette iron-bearing district of Michigan. The pre-Cambrian rocks of the district comprise three series, separated by unconformities. These are the Basement Complex or Archean, the Lower Marquette, and the Upper Marquette, the two latter constituting the Algonkian for this district. All of these are cut by basic intrusives. The pre-Cambrian rocks are unconformably overlain by Cambrian sandstone.

The Basement Complex occurs in two main areas, one north of the Marquette series, called the Northern Complex, and one south of the Marquette series, called the Southern Complex. There are also isolated areas within the Algonkian. The oldest rocks of the Basement Complex are thoroughly crystalline, foliated schists and gneisses. A close field and laboratory study has failed to detect in them any evidence of sedimentary origin. These gneisses and schists have been cut by various igneous rocks at different epochs. The latter occur both in the form of great bosses and in dikes, sometimes cutting, sometimes parallel to, the foliation of the rocks. In the area of the Northern Complex there have been volcanic outbursts, and a vast series of lavas, agglomerates, greenstone-conglomerates, and tuffs have been piled up. By far the greater part of the volcanic material is of an intermediate or basic character.

The Northern Complex is treated under the divisions of Mona schists, Kitchi schists, gneissoid granites, hornblende-syenites, basic dikes, acid dikes, peridotite, and ferruginous veins. The Mona and Kitchi schists are greenstone-schists, which are believed to be largely

[1] Continued from page 541, Vol. VI., this JOURNAL.

[2] The Marquette iron-bearing district of Michigan, by C. R. VAN HISE and W. S. BAYLEY; with a chapter on the Republic Trough by H. L. SMYTH: Mon. U. S. Geol. Surv. No. 28, 1896, pp. 1–607. With atlas of 39 plates. Preliminary report on same district, published in the 15th Ann. Report U. S. G. S., 1895, pp. 477–650.

[3] The Algonkian rocks are described by VAN HISE; the Basement Complex and later igneous rocks are described by BAYLEY; the Republic Trough is described by SMYTH.

recrystallized volcanic materials. Their original forms included both tuffs and lavas. The gneissoid granites and syenites are plutonic intrusive rocks within the greenstone-schists. The basic dikes are mainly diabase. The peridotite is older than the Cambrian sandstone and younger than the greenstone-schists of the Basement Complex. The ferruginous veins are believed to be water-deposited, and were formed previous to the deposition of the Lower Marquette series.

The Southern Complex differs from the Northern Complex in the smaller quantity of greenstone-schists in the former and in the presence in it of the micaceous and hornblendic schists, and the Palmer gneiss. It is treated under the divisions micaceous schists, amphibole-schists, gneissoid granites, Palmer gneiss, and intrusives. The micaceous schists include muscovite-schists, biotite-schists, feldspathic biotite-schists, and hornblendic biotite-schists. They are thought to be mashed acid eruptives. The amphibole-schists include greenstone-schists, hornblende-schists, and micaceous hornblende-schists. They are shown to be mashed basic eruptives. The granites and dike materials are similar in their essential features to the corresponding rocks of the Northern Complex. The granites are younger than the schists, since dikes from them intrude the schists. The Palmer gneisses occur only on the borders of the granite areas, between these and the Marquette sedimentaries, and are apparently in most cases extremely mashed phases of the granites.

The isolated areas of the Fundamental Complex within the Algonkian are chiefly gneissoid granites and schistose greenstones, that differ in no essential respect from the corresponding rocks of the Northern Complex and Southern Complex.

The Lower Marquette series is composed of the following formations, given from the base upward: The Mesnard quartzite, the Kona dolomite, the Wewe slate, the Ajibik quartzite, the Siamo slate, and the Negaunee iron formation. There is no break between these formations; the series is a continuous one.

The Mesnard quartzite is chiefly a metamorphosed sandstone. However, at the bottom of this formation is a conglomerate, which in grading into the sandstone passes through slate and graywacke. The conglomerate is basal, being composed of detritus from the Basement Complex. At the top of the formation is a slate. The Mesnard quartzite is the first deposit of the westward transgressing Lower Marquette sea. By the time the sea had advanced westward a short

distance upon the Marquette district, the Kona dolomite began to be formed, and hence the Mesnard formation is confined to the eastern part of the district. The thickness of the Mesnard quartzite is from 150 to 670 feet.

The Kona dolomite is largely an altered limestone, but it includes interstratified layers of slate, graywacke, and quartzite, with gradation phases between these and the pure dolomite. The Kona dolomite, like the Mesnard quartzite, is confined to the eastern part of the district. The dolomite varies through a slate into the Mesnard quartzite below, and by a lessening of the calcareous constituent gradually passes into the Wewe slate above. The thickness is from 425 to 1375 feet.

The Wewe slate is chiefly a metamorphosed mudstone, but with the slates are conglomerates, quartzites, graywackes, mica-slates, and mica-schists. The Wewe slate, like the two previous formations, is confined to the eastern part of the district. The formation grades into the Kona dolomite below and the Ajibik quartzite above. The thickness is from 550 to 1050 feet.

The Ajibik quartzite, is mainly a metamorphosed sandstone, which in different parts of the district, depending upon various conditions, has been transformed into quartzite, cherty quartzite, ferruginous quartzite, ferruginous cherty quartzite, quartz-rock, and quartzite-breccia. The time of the Ajibik quartzite marks a rapid advance to the west of the Lower Marquette sea, and therefore the formation extends to the western end of the district. In the eastern part of the area the Ajibik quartzite grades down into the Wewe slate, but for the major part of the district it rests unconformably upon the Basement Complex. At many localities contacts and basal conglomerates are known. The Ajibik quartzite grades above either into the Siamo slate or into the Negaunee iron formation. The thickness is from 700 to 900 feet.

The Siamo slate is chiefly an altered mudstone, although locally it is a graywacke or quartzite. The larger area of exposure of the formation is confined to the eastern part of the district, although a belt of the formation runs near the north side of the Marquette series to the west end of the district. The Siamo slate grades into the Ajibik quartzite below and into the Negaunee iron formation above. The thickness is from 600 to 1200 feet.

The Negaunee iron formation is nonfragmental, heavily ferruginous

throughout, and contains the greater iron ore deposits of the district. The formation comprises sideritic slate, which may be grüneritic, magnetitic, hematitic, or limonitic; grünerite-magnetite-schist; ferruginous slate; ferruginous chert; jaspilite, and iron ore. Large quantities of intrusive greenstones are associated with the formation, the masses of which vary in magnitude from great bosses two miles or more long and a half mile wide to small dikes. The largest area of the Negaunee formation is in the east-central part of the district. From this area two belts extend west to the western end of the district. Upon the whole the formation is soft, and occupies lowlands between the more resistant greenstones and the Ajibik quartzites. The formation is underlain by the Siamo slate or Ajibik quartzite, into which it grades, and is overlain unconformably by the Upper Marquette series.

The sideritic slate is the original form from which the other varieties of rock have developed. The grünerite-magnetite-schists were formed by partial recrystallization of the silica, by oxidation of the iron oxide in part to magnetite, by a union of a part of the silica and iron protoxide, producing grünerite, and with the loss of carbon dioxide. The ferruginous slates are the direct result of the decomposition of the iron carbonate and the peroxidation of the iron, with partial or complete recrystallization of the silica. The ferruginous cherts differ from the ferruginous slates in that the iron oxide and the chert are largely concentrated into alternate bands. The jaspilites differ from the ferruginous cherts in that each of the quartz grains of the chert bands is stained red by included hematite. The iron ores resulted from the concentration of the iron oxides through the agency of downward-percolating waters. These concentration-bodies usually occur upon impervious basements in pitching troughs. The pitching troughs are formed by the Siamo slate, the Ajibik quartzite, a mass or dike of greenstone, or by some combination of these. The ore deposits are likely to be of large size where, as a result of the folding, the iron-bearing formation is much fractured, thus permitting the ready access of percolating waters. The ore deposits occur at the bottom of the Negaunee formation, within the Negaunee formation, and at the contact horizon between the Negaunee formation and the overlying Ishpeming formation. From the position of the ore deposits above the impervious formations, it is concluded that their concentration occurred during or subsequent to the folding which took place later than Upper Marquette time.

The Upper Marquette series is composed of the following formations, from the base upward: The Ishpeming formation, the Michigamme formation, and the Clarksburg formation, in conformable succession.

The Ishpeming formation includes two classes of rocks, which are called the Goodrich quartzite and the Bijiki schist. These rocks are sufficiently different to have different formation names, but the Bijiki schist for the west end of the district occupies a part of the horizon of the Goodrich quartzite in the central part.

The Goodrich quartzite includes quartzites, micaceous quartz-schists, mica-schists, mica-gneisses, and at the base a basal conglomerate. For the major part of the district this conglomerate rests upon the Negaunee formation, and the rock is an ore, chert, jasper, and quartz conglomerate. At a few places the Archean rocks are subjacent, and here their materials predominate in the conglomerate. The Goodrich quartzite is confined to the central and western parts of the district. For the major part of the district it rests unconformably upon the Negaunee formation. In places erosion has cut through the Negaunee formation into the Ajibik quartzite, and in a few cases even to the Archean, and here the Goodrich quartzite may be found resting on the lower formations. For the greater part of the area the Goodrich quartzite grades up into the Michigamme or Clarksburg formation, but in the northwestern part of the district it passes up into the Bijiki schist. The thickness is from 600 to 1550 feet.

The Bijiki schist is a banded grünerite-magnetite-schist, which has been derived by metasomatic and dynamic processes from an impure siderite. It is confined to the western part of the district. The Bijiki schist grades into the Goodrich quartzite below and into the Michigamme formation above. The thickness is from zero to 520 feet.

The Michigamme formation includes slates, graywackes, mica-schists, and mica-gneisses. The formation is exposed in a single large belt, running from the center to the western end of the district. It grades below into the Goodrich quartzite, Bijiki-schist, or Clarksburg formation. The thickness cannot be accurately estimated, but it is probably as much as 2000 feet.

The Clarksburg formation is composed predominantly of volcanic materials, embracing basic lava flows, tuffs, ashes, and breccias, which locally are interleaved with or grade into slate, graywacke, or conglom-

erate. Much of the material has been profoundly metamorphosed, and schist-conglomerates, mica-schists, and hornblende-schists have resulted. All of these rocks are cut by dikes and masses of greenstone. The formation is confined to the south central part of the district. The volcanic material was poured out from the number of vents, the more important ones which have been recognized being located near Clarksburg, Greenwood, and Champion. The formation grades into the Ishpeming formation or the Michigamme formation below, and into the Michigamme formation above. The Clarksburg formation belongs in age, either between the Goodrich quartzite and the Michigamme formation, or near the base of the latter. No estimate of the thickness can be given.

The igneous rocks, other than those of the Clarksburg formation, are divided for convenience in discussion into two classes, in the first of which are placed those associated exclusively with the beds below the Clarksburg formation, and, in the other, those cutting also the beds above the Clarksburg. The rocks are all basic. The older rocks occur as dikes, bosses, sheets, and tuff beds, although the latter two are subordinate. The post-Clarksburg greenstones comprise only dikes and bosses. It is conjectured that these later greenstones may be the equivalents of some of the Keweenawan eruptives.

Evidence of the unconformity between the Lower Marquette series and the Basement Complex is clear and abundant. At numerous places in the district the actual contacts of the basal conglomerate of the Marquette series and the Fundamental Complex may be seen. In all of these cases the detritus is most distinctly waterworn, and, while the major part of the material in each case has been derived from the immediately subjacent part of the Basement Complex, other material not occurring in the immediate neighborhood is found, thus showing conclusively that these rocks are not reibungs or fault breccias. There may be mentioned the principal localities at which contacts are well exposed.

At the east end of the south side of the Marquette district there are several localities, from Lake Superior to west of Lake Mary, where a conglomerate is found bearing numerous bowlders of granite, gneiss and schist, identical with the rocks constituting the Basement Complex immediately adjacent. In Secs. 22 and 23, T 47 N, R 26 W, are two islands of the Basement Complex, about which are found magnificent exposures of great bowlder-conglomerate and recomposed granite,

resting with visible contact upon the Basement Complex, and composed of material mainly derived from it. South of the Cascade range, there are again a number of localities from Secs. 34 to 32, T 47 N, R 26 W, where there are basal conglomerates, the great bowlders again being mainly identical with the adjacent granites, gneisses, and schists of the Basement Complex. South of Summit Mountain, in the west half of Sec. 25, T 47 N, R 27 W, is an exposure of the basal conglomerate. The conglomerate grades downward into a schist which is scarcely distinguishable from the Palmer gneiss, with which it is in contact. The next contact to the west is in Sec. 28, T 47 N, R 27 W, where the phenomena are similar to those south of Summit Mountain. At the end of the Republic Trough a conglomerate hangs with visible contact upon the flank of the Archean granite, bearing well rounded waterworn bowlders from it.

At the north side of the Lower Marquette series, and near the east end of the district there is exposed a magnificent basal conglomerate about three miles west of Marquette, north of Mud Lake. The next contacts to the west are at the base of the quartzite east and west of Teal Lake. At one place here the relations are such that the layers of the conglomerate cut across the foliation of the subjacent schists at an acute angle. Still farther west, in Sec. 30, T 48 N, R 28 W, contacts are found in a number of places. West of this point the only actual contact known is north of the Michigamme mine.

The unconformity between the Lower Marquette and Upper Marquette series is also well marked. At the close of Lower Marquette time the land was raised above the sea, gently folded and eroded, and the Upper Marquette sediments were later laid down unconformably upon this floor. In general the discordance between the Lower Marquette series and the succeeding series is not great, being measured frequently by five to ten degrees, at other times by ten to fifteen degrees, and it is only rarely that the plications of the lower series are such as to make the beds abut perpendicularly against those of the overlying series. Erosion has cut deeper in the Lower Marquette series in some places than in others, so that the Upper Marquette series rests upon different members of the lower series. At the east end of the area it left a very considerable thickness of the iron-bearing formation, but in places to the west this formation is quite cut out. Indeed, in places erosion cut through the Siamo slate and the Ajibik quartzite, and in some places even into the Basement Complex. This

particularly occurs in the west and southwest parts of the district, west of Champion and along the Republic Trough, where but few members of the Lower Marquette series were deposited. Even within a short distance the differential erosion was considerable. For instance, at the south end of the Republic Trough the variation was more than 1500 feet.

The Marquette district has been folded in a complex manner. The largest but least conspicuous fold of the district is an anticline having a north-south axis, running through the city of Marquette. This great fold has, especially near its crown—that is, for the eastern six or eight miles of the district—folds of the second order superimposed upon it, making this part of the fold an anticlinorium. The other major anticline belonging to this system of folds is one running north and south through the east end of Michigamme Lake. The major part of the district has been affected, however, by much more effective pressure in a north-south direction, so that the folds in an east-west direction are much more conspicuous than the north-south folds of greater wavelength and greater amplitude. As a result of the north-south pressure, the Upper and Lower Marquette series together have been bent into a great abnormal synclinorium. This synclinorium is of a peculiar and complicated character. The Algonkian rocks on either side of the trough have moved over the more rigid Archean granite, and, as a consequence, on each side of the Algonkian trough a series of overfolds plunge steeply toward its center, producing a structure resembling in this respect the composed fan structure of the Alps. There is, however, this great difference between the Marquette structure and that of the Alps, that in passing from the sides of the trough toward the center, newer rocks appear rather than older ones, so that in the center of the synclinorium the youngest rocks are found. It is as if the composed fan folds of the Alps were sagged downward, so that the structure as a whole is a synclinorium rather than an anticlinorium. This form of folding has been elsewhere defined by Van Hise[1] as an abnormal synclinorium. The folding is closer in the western part of the district than to the east. The strikes of most of the exposures of the district are mainly controlled by the east-west folds, but, at the east and west ends of the areas of the formations, the larger north-south folds already described control.

[1] Principles of North American Pre-Cambrian geology, by C. R. VAN HISE, 16th Annual Report U. S. Geol Surv., Part I, 1896, p. 612.

The rocks of the district have yielded to the folding in different ways. Where brittle the close plications have resulted in their being fractured through and through, and in many places they pass into reibungsbreccias. These phenomena are particularly prevalent in the Negaunee iron formation and in the quartzites. The more plastic formations have yielded without major fracturing, but in a minor way they show everywhere the effects of deformation. A microscopical study shows that not a cubic inch of material has escaped dynamic action. While, as a further consequence of dynamic action there has been local faulting at various places, with two or three exceptions, no important faults have been observed in this district.

Because of the varying strength and texture of the various beds and formations, the readjustments necessary in folding took place in large measure between the different formations and between dissimilar beds of each formation. As these layers were rubbed over one another, schistosity was developed parallel to the bedding in many places. The unconformable contacts between the Upper Marquette and Lower Marquette series, and between the Archean and Lower Marquette series, were the greatest planes of movement, and adjacent to them the rocks of both the series were rendered schistose. In the nearly homogeneous Michigamme and other slates there apparently occurred an actual flowage. Here there is frequently a discordance between the cleavage or schistosity and the bedding.

It is inferred from the phenomena of deformation that, when folded, the rocks which are now at the surface were buried under a thickness of several thousand feet of sediments, not impossibly as much as ten thousand feet. On the other hand, it appears that the formations were not so deeply buried as to be beyond the sustaining strength of strong rocks like quartzites, or else the layers of these rocks would have been folded without the production of reibungsbreccias, as in the case of the Doe River quartzite of Tennessee.

As shown by the above facts, the Marquette district furnishes a beautiful instance of deformation in the lower part of the zone of combined fracture and flowage.[1]

The Lower Marquette and Upper Marquette series are correlated with the Lower Huronian and Upper Huronian series of the north shore of Lake Huron. The reasons are stated in previous publica-

[1] Principles of North American Pre-Cambrian geology, by C. R. VAN HISE. 16th Annual Report U. S. Geol. Surv., Part I, 1896, pp. 601–603.

tions, and are not repeated.[1] The succession in the Menominee district of Michigan, as given by Smyth,[2] is compared with that of the Marquette district, and points of similarity and difference noted. It is shown that the series of the two districts may be roughly correlated, but that closer correlation may not be attempted until more detailed studies are made in the Menominee district.

Newett[3] gives a sketch of the Marquette iron-bearing district of Michigan, and publishes a geological map of the district compiled from a map of the Upper Peninsula in the possession of the Michigan Geological Survey. The iron ores occur in the Huronian rocks, of which there are some thirty members. This series of rocks has been subjected to enormous lateral pressure, resulting in foldings in the strata. In the folds the ore is found generally in lenticular masses. The Huronian rocks are cut by eruptive rocks, which have played an important part in assisting in the concentration of the ores.

Gresley[4] describes peculiar markings in iron ore from the Chapin mine of Iron Mountain, Mich., which are thought by H. S. Williams, by Schuchert and by Walcott to be trails of organic origin.

Comments.—At various places in the Menominee district, including the Chapin mine, the Cambrian sandstone unconformably overlies the ferruginous schists of the Huronian. At some localities the lowest horizon of the Cambrian is an iron ore, which has been mined. The question arises whether or not the organic remains referred to by Gresley are contained in the original ore of the Huronian or in the detrital ore of the Cambrian. As the specimens were found in the ore after it had been shipped from the district, it seems impracticable to answer this question, and therefore it is unsafe to conclude that the organic markings are of pre-Cambrian age.

[1] Correlation papers — Archean and Algonkian, by C. R. Van Hise. Bull. U. S. Geol. Surv., No. 86, 1896, pp. 183–186.

Principles, cit., pp. 796–799.

[2] The Lower Menominee and Lower Marquette series in Michigan, by H. L. Smyth. Am. Jour. Sci., 3d series, Vol. XLVII, 1894, pp. 216–223.

[3] The Marquette Iron Range of Michigan, by G. A. Newett. Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 87–108. With geol. map.

[4] Organic markings in Lake Superior iron ores, by W. S. Gresley. Science, new series, Vol. III, 1896, pp. 622–623.

Van Hise[1] describes baselevels in the crystalline rocks of central Wisconsin and Keweenaw Point. In the Wisconsin district the Archean and Huronian rocks occupying the area are truncated to an even baselevel with an apparent southerly slope. The altitude is about 1450 feet.

On Keweenaw Point the peaks of the main trap range rise to so nearly the same altitude that they form an apparent plain, which is considered an ancient baselevel. The altitude of this plain is about 1350 feet. Certain peaks, consisting of hard quartz-porphyry and felsite, have resisted weathering, and stand above this plain.

The central Wisconsin plain has not been so deeply dissected as the Keweenaw Point area, but this is explained by the fact that it is not so near either of the great lakes, and therefore erosion has not been so effective over it.

From the proximity of the central Wisconsin and Keweenaw Point baselevels, and from the fact that they have nearly the same altitude, it is concluded that the baselevels of the two districts are probably but parts of a far more extensive baseleveled region resulting principally from the subaërial erosion of Cretaceous time, and perhaps also, in part, from the marine denudation of the Cretaceous.

Hubbard[2] describes the relation of the copper vein at the Central mine, Keweenaw Point, to the Kearsarge conglomerate. The veins of Keweenaw Point belong largely to one system, and are confined principally between T 57 N, R 32 W, and the northeast extremity of the Point. The copper-bearing formation between these limits dips N 33° E, at the first locality, to south of east at the last, and the veins are nearly at right angles to the formation. The Central mine is situated in Sec. 23, T 58 N, R 31 W, about eighteen miles northeast of Calumet. Here there has been a northerly sliding of the formations above the Kearsarge conglomerate, as a result of which the copper vein in the overlying formations is found to stop abruptly at the Kearsarge conglomerate. In this mine is the eastern edge of the basin in which the Kearsarge conglomerate was deposited.

[1] C. R. VAN HISE, A central Wisconsin baselevel, Science, Vol. IV, 1896, pp. 57–59; A northern Michigan baselevel, *ibid.*, pp. 217–220.

[2] The relation of the vein at the Central mine, Keweenaw Point, to the Kearsarge conglomerate, by L. L. HUBBARD, Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 74–83.

Winchell, H. V.,[1] gives a brief sketch of the iron ranges of Minnesota. Along the north side of the Mesabi range is a ridge of Archean syenite and granite, flanked on both sides by crystalline and semicrystalline schists. This ridge is called the Giant's Range. On the south side of the Giant's Range, lying at times nearly up to its summit, are the outcropping edges of Taconic or Upper Huronian strata, which overlie unconformably the syenites and schists. These are in turn overlapped to the south by eruptive rocks of Keweenawan age and by Cretaceous sediments. The ore is soft hematite, which lies at low angles from the horizontal, usually covered merely by drift.

The geology of the Vermilion Range is not yet understood. The iron ores are solid and massive, except at the Chandler mine, where they are brecciated, and occur in steeply inclined lenses between walls of schist, extending to an indefinite depth.

Lawson[2] describes a family of basic plutonic orthoclase rocks rich in alkalies and lime, which he names malignite, as occurring in the form of a laccolite in the Coutchiching schists of Poohbah Lake. The malignites vary from basic nepheline-pyroxene malignite through garnet-pyroxene malignite to amphibole malignite.

Coleman[3] makes a second report on the gold fields of western Ontario, including the area between Finmark, near Thunder Bay, and the Manitoba boundary, and between Minnesota and Keewatin on the north shore of Lonely Lake. This visit confirms his impressions of the geology of the area as given in the preceding report of the bureau.[4]

At many places the Laurentian rocks show an eruptive contact with the overlying rocks, showing that they must have been consolidated later than the Huronian. Coleman suggests that it would be more logical to confine the name *Laurentian* to the oldest complex of thoroughly crystalline rocks serving as a foundation for all succeeding rocks, and to describe the clearly eruptive rocks which penetrate the

[1] The iron ranges of Minnesota, by H. V. WINCHELL, Proc. Lake Superior Mining Inst., Vol. III, 1895, pp. 11–32.

[2] Malignite, a family of basic plutonic orthoclase rocks rich in alkalies and lime, by ANDREW C. LAWSON, Bull. Dept. of Geol., Univ. of Cal., Vol. I, 1896, pp. 337–362, Pl. 18.

[3] A second report on the gold fields of western Ontario, by A. P. COLEMAN, Fifth Rept. Bureau of Mines, Ontaria, for 1895, Sec. II, pp. 47–106, 1896.

[4] Reviewed in this JOURNAL, Vol. IV, pp. 744–745.

overlying Huronian schists as eruptives, of later age than at least the earlier members of the Huronian. If this were done, very little of the territory under consideration could be mapped as Laurentian —perhaps none of it with certainty. However, the discrimination may not be made until more detailed work has been done in the district.

Coutchiching mica-schists and gneisses, though probably present, have not been certainly recognized. The series of eruptives, pyroclastics, and less common waterworn clastics, Lawson's Keewatin, is of widespread occurrence, and of great importance as containing the gold-bearing veins of the district. It is spoken of under the general term Huronian.

Blue[1] sketches the geological history of the New Ontario, which includes that part of the province of Ontario lying beyond the Matawan and French rivers, and the Nipissing, Huron, and Superior lakes, to the north and west boundaries of the province. Laurentian and Huronian rocks form highlands which in Archean time were the most important physical feature of North America, sweeping in a curve through what is known in our time as the regions of Labrador, Quebec, Ontario, and the Northwest Territories. While there are large areas in which eruptive masses of granite and gneiss have penetrated the Huronian rocks, and thrown them into folds, proving their later age, in general the reverse is the case, the Huronian resting unconformably upon the Laurentian, and being of later origin. The Huronian is overlain unconformably by Cambrian rocks, under the Cambrian being included Animikie, Nipigon, and Potsdam rocks.

Comments.—The term *Cambrian*, as here used, covers Animikie, Keweenawan, and Potsdam rocks. The two former have ordinarily been regarded as pre-Cambrian.

Dowling[2] reports on the geology of the country in the vicinity of Red Lake and part of the basin of Berens River, in the district of Keewatin, Canada. The rocks exposed are all Archean, including gneisses

[1] The New Ontario, by ARCHIBALD BLUE. Fifth Rept. Bureau of Mines, Ontario, for 1895, pp. 193–196, 1896.

[2] Report on the country in the vicinity of Red Lake, and part of the basin of the Berens River, District of Keewatin, by D. B. DOWLING, Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part F, 1896, pp. 54. With geological map.

and granites classed as Laurentian, and folded schists and greenstones classed as Huronian.

The Laurentian rocks prevail over a much greater area than the Huronian rocks, being seen along the White and Berens rivers, on Lac Seul, and on the English and Matawan rivers. They are gneisses and granites, the latter in places apparently intrusive in the former, as along the headwaters of the Berens River. The granites are occasionally intrusive also in the Huronian to the south.

The Huronian rocks are a series of schists, limestones, and water-deposited volcanic materials. They occur in two main areas. The eastern one is in the vicinity of Clearwater and Woman lakes. The eastern boundary of this area has not been defined; to the west, the Huronian is in contact with the Laurentian. From the southwestern part of the area, a belt extends southwest to the vicinity of Shallow Lake. The western area of Huronian occurs in the vicinity of Red Lake, and is surrounded by and incloses areas of Laurentian granite and gneiss.

Contacts of the Laurentian and Huronian rocks are described for numerous localities. The contacts are "generally of a brecciated character, the gneisses and granites while in a plastic condition surrounding and inclosing the Huronian schists" (p. 40).

The Huronian rocks are similar in many respects to the Keewatin series of the Lake of the Woods and Rainy Lake districts, to the south: but the Huronian of the area under discussion includes dark blue limestone, and conglomerates with jasper pebbles, both very similar to those of the typical Huronian area north of Lake Huron, and the rocks are accordingly mapped as Huronian.

The Coutchiching, supposed by Lawson to underlie the Keewatin of the Rainy Lake country, is possibly here represented by a small area west of Shallow Lake, mapped as Huronian. However, at Gull Rock Lake, rocks which still more resemble the Coutchiching of the Rainy Lake region are found to be but highly altered Huronian beds in contact with the Laurentian, which, when followed along the strike, take on the general aspect of the remainder of the Huronian of the district.

GENERAL COMMENTS.

In the articles by Blue, Coleman, and Dowling the term *Laurentian* is used to cover both the ancient basement upon which the Huronian rocks were deposited, and later granitic intrusives, although Coleman

recognizes the fact that the logical course is to confine the term Laurentian to the older rocks. This usage of the term is a serious obstacle to the progress of structural geology in this region, for two entirely different series of rocks are confused. Plainly the rocks called Laurentian upon which the Huronian was deposited are pre-Huronian; it is equally certain that the granites called Laurentian which cut the Huronian are Huronian or post-Huronian in age. So long as these two classes of rocks are confused on the maps, no such thing as a structural map of the area northwest of Lake Superior is possible.

C. K. Leith.

Reviews.

Elemente der Gesteinslehre. By H. Rosenbusch, Stuttgart, 1898.

That this book presents the essential features of Professor Rosenbusch's lectures on petrology as they have been developed during thirty years of his experience, is sufficient guarantee that the work is a most valuable contribution to the didactic side of the subject. That those who are not permitted to listen to Professor Rosenbusch in Heidelberg may read his careful presentation of the essential characteristics of rocks is fortunate, and the appearance of the book so long looked for is a fact upon which many may congratulate themselves. No satisfactory review of a work so full of matter can be given without close and exhaustive reading, but some insight into its character may be gotten without exhausting the subject.

In attempting to condense the wide range of facts and speculations relating to igneous, sedimentary and metamorphosed rocks into the space of an elementary text-book, minor details and qualifications of statements are minimized or omitted, thereby sharpening the outlines of the images presented to the mind. As a necessary result we find in some cases positive statements where we should expect tentative ones, and a tone of finality in portions of the work where we had not expected it. This is of course noticeable in the introductory portions of the parts devoted to the three categories of rocks.

The general introductory chapter, after defining a rock, and the scope of petrology, treats of the methods of investigating rocks, geologically, mineralogically and chemically, special attention being given to the chemical characteristics. Definitions of the principal terms used in connection with the mineral constituents are followed by an account of varieties of parting and jointing of rocks and a brief statement of their formation and classification.

Part I deals with eruptive rocks, first considering their constituents as chemical compounds and as minerals, and the relation of the latter to one another both as to the order of their crystallization and as to their morphology. Then their geological characteristics are described.

Considerable space is given to their texture or structure, with special reference to their interpretation in terms of the occurrence of the rocks and the order of crystallization of the mineral constituents. The age of igneous rocks and their alteration and metamorphism are briefly treated, and a system of classification is given without discussion of the principles on which it is based. The classification followed is the same as that employed in Professor Rosenbusch's work on the Microscopical Physiography of the Massive Rocks, with slight modification in the divisions embracing "*Tiefengesteine*" and "*Ganggesteine*." An age distinction has disappeared from the grouping of "*Ergussgesteine*," so that liparite and quartz-porphyry are described together.

The description of each class of rocks embraces the mineralogical and microscopical characteristics, besides the chemical composition, which is shown in ample tables of analyses both of the rocks as a whole and of separate mineral constituents. This feature is a very marked addition to the treatment of the subject in the Microscopical Physiography of Massive Rocks. The metamorphism of igneous rocks themselves and that produced by them upon adjacent rocks is described in immediate connection with the description of the unaltered rocks.

The part devoted to stratified rocks follows the same general plan as Part I. The rocks are classified under the heads of: precipitates, psephites and psammites, silica rocks (not previously described), carbonate rocks, iron rocks, clay rocks, porphyroids and fossil fuels. In this part also, considerable is introduced that belongs to the subject of metamorphism.

Part III treats of the crystalline schists, their composition, geological occurrence, texture and classification. Crystalline schists are said to be eruptive or sedimentary rocks that have attained geological transformation chiefly through the coöperation of geo-dynamic agencies. The classification of these rocks is that commonly used and the author recognizes its artificial and unsatisfactory character but considers our knowledge and judgment in the matter not yet sufficiently advanced to warrant any attempt at its betterment at this time. The order followed is: gneisses, mica-schists, talc-schists, chlorite-schists, amphibole and pyroxene rocks, serpentine, rocks of the lime series, magnesia series, iron series, and emery (corundum). In each class the mineral and chemical compositions are described together with the texture and the varieties of rock embraced within each class.

Whatever may be our view of the position taken by Professor Rosenbusch upon certain mooted questions in petrology, we must acknowledge the great value of this recent work, and congratulate the author upon its publication. J. P. I.

A Text Book of Mineralogy with an extended treatise on Crystallography and Physical Mineralogy, by E. S. Dana, New York, John Wiley & Sons, 1898.

This is a new edition of Professor Dana's former text-book entirely rewritten and enlarged. It consists of four parts devoted to crystallography, physical mineralogy, chemical mineralogy, and descriptive mineralogy, and contains an appendix treating of the drawing of crystal figures, and of projections, besides one giving tables to be used in the determination of minerals.

The relation of crystal form to other physical properties and to the probable molecular structure of crystals is set forth in the introductory paragraphs of Part I, and the grouping of the crystal forms is made in relation to the thirty-two classes of symmetry. For this reason it would seem that a more logical arrangement of the subject would place the physical mineralogy first and the crystallography afterwards.

The arrangement of the types of crystal forms although referred to the classes of symmetry is the order usually employed in elementary treatises, namely, the group with the most complex symmetry first. The necessity for this order of arrangement is questionable.

The treatment of the six crystallographic systems is quite full and in addition to the description of the symmetry and principal forms are given their spherical projection and the mathematical relations of each system. Compound or twin crystals and the irregularities of crystals are described at length and are profusely illustrated.

The physical characters of minerals are treated briefly in connection with those of cohesion, elasticity, and relative density, as well as those related to heat, electricity, and magnetism. The optical properties are considered at greater length, both as to the principles involved and their application to the optical investigation of minerals. In this respect the improvement over former editions of the Text Book is marked. The part devoted to chemical mineralogy includes a statement of the general principles of chemistry which apply to minerals

and a brief description of methods of chemical examinations of minerals.

The descriptive mineralogy is an abridgment of the sixth edition of Professor Dana's System of Mineralogy and possesses most of the advantageous features of the larger work. However, much of the material of the latter work is necessarily excluded from a text-book.

Perhaps the most striking feature of the new edition of this Text Book of Mineralogy is the condensation of the material, a great amount of information being compassed by so few pages. Its adaptability for class instruction, however, has yet to be tested, and it is hoped that it will prove satisfactory. Its need has been long felt and Professor Dana is to be thanked for its preparation. It is regrettable that the figures used for illustration vary so greatly in merit. While most of them are excellent, some are quite defective or are poorly printed so that the lettering is obscure or the edges of crystals confused.

J. P. I.

Manual of Determinative Mineralogy with an introduction on Blowpipe Analysis, by GEORGE J. BRUSH. Revised and enlarged, with entirely new tables for the identification of minerals, by Samuel L. Penfield. Fifteenth edition. John Wiley & Sons, New York. Chapman & Hall, London, 1898.

In 1896 a revision of the introductory chapters of this book, relating to blowpipe analysis and the chemical reactions of the elements, was published, and was reviewed in this JOURNAL, Vol. V, p. 86. The character of the work published at that time was of so high an order as to raise expectations regarding the promised revision of the tables for the identification of minerals. These expectations have been fully satisfied by the present publication. The advancement of mineralogical knowledge since the tables were first arranged in 1874 by Professor Brush has necessitated their expansion and rearrangement and has permitted of their being rounded out into more perfect form. The new tables are not only almost double the length of those published two years ago, but are more complete in the amount of data furnished under each mineral species. And, while the number of species of minerals in the new tables is much larger than formerly, the student is saved from confusion by the printing of the commoner kinds in stronger type than that used for the rarer ones. There are frequent

evidences of the care taken by the author to prevent errors on the part of the student, and, with the detailed methods of procedure described in the introductory chapters, it would seem as though everything had been done to enable the student to fit himself to identify minerals by all means except those based on their optical behavior in polarized light.

A chapter has been introduced into this edition treating of the crystal forms of minerals in a manner especially adapted to beginners. The treatment is necessarily brief as regards the principles of crystallography. Particular stress has been put upon the illustration of the subject. The number of figures is not only large as compared with the extent of the text, but care has been taken to employ examples most likely to be met with by the student, and the drawing of the figures has been well done. The method of treatment is mainly descriptive, and, though conceptions of symmetry are introduced, and excellent figures representing the relative positions of different axes of symmetry are given in connection with various subdivisions of crystal forms, the application of symmetry to the forms or its relation to them is left to the student to work out. The arrangement of the groups or systems of crystal forms is that ordinarily followed, beginning with those having the most complex symmetry, holohedral isometric crystals, and finishing with crystals without symmetry, the triclinic. Subdivisions of each of these systems are called normal, when holohedral according to former usage, and when having less symmetry than the highest in each system, that is, when belonging to what have been called hemihedral or tetartohedral, they are named after some characteristic crystal form or after some mineral characterized by such a form.

In all parts of the book there are evidences of the great care taken by the author to render the subject intelligible to persons taking up the study of minerals for the first time, and there can be no question as to the success of the endeavor.

J. P. I.

The Lower Cretaceous Gryphæas of the Texas Region. By Robert Thomas Hill and Thomas Wayland Vaughan. Bulletin No. 151, U. S. G. S. Washington, D. C.

The bulletin presents a careful study of that group of fossil oysters which has generally been referred to *Gryphæa pitcheri* of Morton. The authors vigorously criticise the opinions and descriptions formerly

published, and dwell with laudable earnestness upon the confusion resulting from carelessness and from opinions based upon inadequate investigation. The great variability of the *Ostreidæ* is emphasized, but the authors correct the opinion previously held that this variability destroys their value in stratigraphy. They show that the hemeræ of many forms have well defined limits and are, therefore, of the greatest use in determining horizons. No classification yet given is satisfactory for the Texas *Ostreidæ*. The forms are tabulated provisionally under the old familiar names.

After this discussion, which deals in some measure with the family in general, the authors confine their attention to the specific object of the paper. The various forms which have been referred to *Gryphæa pitcheri* are discussed from a historical standpoint and their stratigraphic and geographic distribution noted. The species of the group are specifically defined and many data given regarding their development and methods of growth, and lastly, something of their phylogeny. A large part of the bulletin is taken up with plates showing the various species at different stages of growth and the individual shells in different positions. The figures formerly published are also reproduced for comparison. The work is especially commendable for careful investigation and clear-cut presentation. W. T. LEE.

Le Granit des Pyrénées et ses phénomènes de contact—Premier memoir: Les contacts de la Haute-Ariège, par M. A. LACROIX, Professeur de Minéralogie au Mus. d'Hist. Nat. Bull. des serv. de la carte géol. de la France. No. 64, tome X. Paris, 1898.

The area which has furnished the results published by M. Lacroix in this bulletin is situated in the very mountainous southern tract of the Departement of the Ariège, about 100^{km} southeast by south of the city of Toulouse. The Ariège, one of the head waters of the Garonne, flows through the region. Most emphasis is laid on the phenomena of contact exhibited on the right bank of the stream, since the exposures are considerably more accessible and continuous than on the left bank. The facts of observation on both banks are, however, accordant.

This, the first memoir on the granite massifs of the Pyrénèes, is devoted to a purely mineralogical treatment of igneous contacts, which

of itself cannot fail to impress the reader with a sense of the abundant store of facts from which M. Lacroix has drawn his interesting and even startling conclusions. These refer to the prime topics of exomorphic and endomorphic metamorphism and the *mise en place* of the granite, on all three of which the investigations of M. Lacroix shed new light.

The granite occurs in the form of a broad stock stretching some 50^{km} from east to west, and the bulletin refers particularly to the contacts at the western end. The rock is a normal coarse-grained granitite, sometimes, though never at the contacts, charged with phenocrysts of microcline several centimeters long. At the contacts it is filled with an extraordinary number of inclusions of the country rocks.

The latter are composed of slates and quartzites with non-magnesian limestones, either massive or interrupted with interbedded slaty layers. All of these rocks have been affected, often profoundly, by contact metamorphism. To this cause is to be attributed the development of a micaceous character, with garnet, cordierite, and sillimanite common in the contact belt. But the most important determination of this new crystallization is that of the existence of orthoclase and of the triclinic feldspars in the micaceous slate zone (*leptynolites*) in amounts which make the feldspar, either the predominant constituent or less abundant, even to its appearing only as scattering grains. This feldspathization has occurred by the process of "imbibition" or by the injection of minute granite apophyses *lit par lit.* The quartzites are similarly feldspathized and rendered micaceous, though in less marked degree than the slates. The white and black limestones, on the other hand, are much more affected, containing grossularite (*grenatite*), vesuvianite, various pyroxenes and amphiboles, epidote (*epidotite*), and the triclinic feldspars from oligoclase to anorthite (*Cornéennes feldspathiques*). Marmorosis is common. On p. 48, M. Lacroix has given a clear statement of the theory of feldspathization and of the part played by the *agents minéralisateurs* in the recrystallization of metamorphic belts. As is well known, he is at one with MM. Fouqué, Michel Lévy, Barrois and others who contend for an actual migration of granite substance from an intrusive granite stock in the presence of mineralizing agents, into the country rock, as well as for the possible removal of certain elements in the exomorphic contact zone under the same conditions of intrusion. A detailed argument for this position is given in Chapter III; its analysis would be beyond the scope of this review.

It is particularly in the study of endomorphic contact action that the bulletin demands the attention of petrographers. While the slates do not seem to have exerted any very pronounced effect on the granitite except in the way of slightly altering its structure, the limestone contact is one pronounced, both from the quality of the changes wrought and from their great areal extent, to be the most noteworthy phenomenon of the region. By the assimilation of the limestone, the granitite successively loses the alkaline feldspars, orthoclase, microcline and anorthoclase, and lastly, quartz, and gains other constituents rich in lime, the basic plagioclases and hornblende. The result is to produce a gradual replacement of the pure granitite magma in the massif by secondary mixtures which have crystallized out as hornblende-granitites, quartz-diorites, diorites, norites and hornblendites. Biotite and hornblende appear in the whole series. When, finally, olivine replaces all the feldspars, the resulting rock, though again the product of assimilation in the same way as the more acid rocks just enumerated, is an amphibole peridotite! The evidences for the fact of magmatic incorporation are exceptionally strong; they may be summarized as follows:

1. Field observations in connection with many localities of actual contact and the study of numerous thin sections showed ordinarily an insensible transition in mineralogical characters from the normal granitite to the basic types.

2. These hornblende rocks are developed only in zones of contact between typical granitite and the limestone, or else in bands which represent the prolongation of limestone layers stretching out into the granitite—a significant mode of occurrence emphasized in the memoir. Such basic bands, extending through the granitite from one end of an interrupted limestone layer along its strike to the corresponding end on the other side of the stock, are interpreted as being the product of recrystallization of mixed granite magma and digested limestone during a prolonged static condition of the igneous rock—that is, a period of quiescence as regards ascensional or lateral movement in the mass. It is hard to resist the conclusion that the map and numerous cross-sections of M. Lacroix prove such a long continuance of the limestone in contact with the particular magma now crystallized and visible where erosion has laid bare the zones of passage; and, moreover, that this fact explains the peculiarly favorable case for the proof of assimilation. The present reviewer is of opinion that the lack of

evidence for clearly defined endomorphic action leading to serious modification of eruptive magmas is, in many cases, due to a removal of the mixed zone of assimilation from contacts by bodily movement of the magma. Such a period of active assimilation and removal is followed by another of limited or no power of assimilation, during incipient cooling, and that stage by a third marked by the crystallization of essentially pure magma in contact with country rock, perhaps metamorphosed but not incorporated.

3. A striking argument for the modification of the granitite in this manner is afforded by certain inclusions within it, described as surrounded by the hornblendic basic types identical with those characterizing the main contacts.

4. No independent dikes, apophyses, or stocks of the basic rocks occur in the region, and on the right bank of the Oriège, at least, there is no dynamic action sufficiently intense to explain the presence of diorites, etc., in the granitite by any system of cross-faults.

5. Lastly, the absence of chilling phenomena in the stock, the intensity of the exomorphic metamorphism, the enormous number of apophyses in the slates, as well as other facts, all tend to show a condition of high temperatures for a long period, and of abundant mineralizers which are permissive of the large amount of recrystallization necessary to explain the occurrence of the basic rocks.

The mode of intrusion is implied in what precedes — a *mise en place* by progressive assimilation of the overlying terranes. The proofs of absorption of the quartzites and slates are not so strikingly manifest as those in the case of the limestone, but they are regarded by M. Lacroix as equally valid. On the other hand, neither block-faulting, nor the batholithic, nor the laccolithic hypothesis seems to be admissible.

On the whole, the memoir is seen to have its chief importance in upholding first, the doctrine of feldspathization of the metamorphic aureole about an intruded granite by the addition, in the presence of mineralizers, of feldspathic material from the granite's own mass; secondly, the doctrine of assimilation; and, lastly, the theory of the *mise en place* of intrusive granites, as enunciated by M. Michel Lévy. It is safe to say that, from the point of view of field observations and of comparative mineralogical study, these tenets of the French school of petrographers have never had in a single locality such strong confirmation. We shall look forward with interest to the forthcoming memoir

on the chemical relations of the rocks of this region. It may be that the analyses will explain certain difficulties which have suggested themselves, almost as a matter of course, in the way of explaining the formation of such minerals as hornblende and olivine (especially the latter) in the endomorphic zone of recrystallization. R. A. DALY.

RECENT BIBLIOGRAPHIES.

Bibliography and Index of North American Geology, Palæontology, Petrography, and Mineralogy for 1896. By F. B. WEEKS. (Bull. U. S. Geol. Surv., 149, 152 pp. Washington, 1897.)

Bibliografia Geológica y Minera de la República Mexicana. By R. AGUILAR y Santillán. (Bol. 10, Inst. Geol. de Mexico. 158 pp. Mexico, 1898.)

Students and workers in geology everywhere will be glad to receive the two papers here mentioned. The value of a well compiled and carefully edited bibliography is too well recognized to need any mention. To all active workers such books are indispensable. The two under review, fortunately, are both excellent. Mr. Week's good work in this line needs no introduction. It only remains to commend and to note the broadened scope of the bibliography. In its preparation 108 serials were examined, the number including several devoted to economic phases of geology and not previously listed. As usual the abstracts are concise, but are quite sufficient to determine the scope of the paper. The full indexes are especially valuable.

The bibliography of Mexico is especially helpful, because of the previous absence of any paper thoroughly covering the field. The author has had more than the usual difficulties, due to poor library facilities, the scattered and incidental nature of the papers, and the presence of broken sets of short lived serials. In the face of such materials there must necessarily be a certain amount of selection. Not all the papers listed are strictly geological but all will doubtless be helpful. At first glance the 1953 titles included seem formidable, and one is surprised at the amount which has been written, but a more careful examination shows, as remarked by the Director in his introduction, that the great majority of the papers written on the geology of Mexico are really technical engineering papers, and deal with geology

but incidentally. The present active geological survey of Mexico has a practically new field, and in view of this and the difficulties of communication over much of the republic, the rapidity of its publication and the high class of the work, deserve the heartiest recognition. Among the publications of the survey the present one will for sometime to come rank among the more useful.

H. F. B.

Geological Survey of Kansas, Vol. III, 1898. By DR. E. HAWORTH, geologist, and MR. W. R. CRANE, assistant geologist and chemist.

Volume III is a special report on Kansas coals and treats of the coal mines and coal mining of the state in all their various aspects. The volume is divided in two parts.

Part I is by Dr. Haworth and deals with the general stratigraphy of the Kansas Coal Measures. Numerous detailed accounts of the strata are given to enable the reader to understand the general geological conditions of the Coal Measure area of the state. The geology of the area is further shown by the records of many deep wells with drawings illustrating the strata as shown by the wells, and in addition to these many geological sections crossing the state in different directions are given.

The following facts are gleaned from Dr. Haworth's report. The Mississippian or subcarboniferous outcrop occupies an area of about forty-five square miles in the extreme southeastern part of the state. The strata dip under the other formations of the state and their westward inclination is about 17 feet per mile, on the average. The Coal Measures proper occupy the eastern third of the state and constitute a mass of alternating layers of limestones or sandstones and shales aggregating 3000 feet in thickness. The limestones are similar in general character but the lower ones are more nearly crystalline, of finer texture, and denser in appearance. The following divisions of the Coal Measures, named in order from lowest to highest, are recognized: (1) The Cherokee shales; (2) The Oswego limestone; (3) The Labette shales; (4) The Pawnee limestone; (5) The Pleasanton shales; (6) The Erie limestone; (7) The Thayer shales; (8) The Iola limestone; (9) The Lane shales; (10) The Garnett limestones; (11) The Leroy shales; (12) The Oread limestone; (13) The Lecompton shales and Elgin limestone.

Part II of the report is by Mr. W. R. Crane and deals with the detailed stratigraphy as exhibited at the mines, the geographic location of the coal fields, the chemical and physical properties of the coal, mining methods and mining machinery, statistics of coal companies and coal mining laws. It contains the best exposition of the phenomena of "horsebacks" in the coal that has yet been published. The subject is fully illustrated by clear-cut drawings. Mr. Crane thinks the "horsebacks" are the result of fissures produced by vibratory movements of the strata, the fissures thus produced being filled with clay, either by the removal of pressure or by "creeping," these vibratory movements, he thinks, in all probability accompanied the Ozark uplift. Rolls and "bells" and other stratigraphical phenomena are explained.

According to the author there are 15,000 square miles of productive coal fields in Kansas but only a small proportion of this area is being worked at the present time. The mines most extensively worked are located in the southeastern part of the state. Across the coal area the percentage of fixed carbon in the coal and the value of the coal (selling price) increases from northwest to southeast. Coal is mined by stripping, drifting, pitting and shafting. In the shafts mining is carried on by means of "the long wall system" or "the room and pillar system."

To the author's exposition of the chemical and physical properties of the coals the greatest importance is attached. He performed the work in a very elaborate manner, the tests being made in many different ways, all the results of which are finally placed in a general summary. The illustrations of machinery, etc., used in the article are from the pen of the author and attest his ability as a draughtsman.

W. N. L.

Twenty-second Annual Report Indiana Geological Survey. W. S. Batchley, State Geologist, Indianapolis, 1898.

The Twenty-second Annual Report of the state geologist gives a detailed statement of the work of the department of geology and natural resources, for the year 1897. Among the subjects treated in the volume is a paper on the "Geological Scale of Indiana," by W. S. Batchley and Geo. H. Ashley. This paper shows the geological formations of Indiana in vertical section, and gives the time, character of the rocks, and subdivisions of each group.

A paper on "The Geology of Lake and Porter Counties," by W. S. Batchley, is devoted mainly to the physiography of the two counties. The author states that the discussion is limited to this phase of geology "since not a single outcrop of rock occurs in the two counties." A considerable portion of the paper is devoted to the discussion of glacial phenomena.

An economic paper by the same author discusses "The Clays and Clay Industries of Northwestern Indiana." The paper treats in some detail of the origin, varieties, properties, impurities of clays and their analyses. Statistics are also given concerning the clay industry.

"Report on the Niagara Limestone Quarries" is the subject of a paper by August Foerste. This report contains a discussion of the uses, properties, and distribution of the stone. From this paper we learn that the variety known as "Laurel limestone" is the most valuable variety; that it occurs in natural slabs, is easily quarried, requires little dressing, is of a handsome color, and is very hard and durable.

The palæontology of the state receives attention through E. M. Kindle, who has prepared a "Catalogue of the Fossils of Indiana." The report also indicates the geological horizon of the species, and is accompanied by a bibliography of Indiana palæontology.

A contribution to the ornithological literature of the state is found in a paper entitled "The Birds of Indiana," by A. W. Butler. The paper contains descriptions of 321 species which have been identified within the state. It also treats of the songs, habits, and times of arrival and departure, of the birds.

Other papers in the report discuss mines, natural gas, and petroleum.

W. N. L.

Sixth Annual Report Iowa Geological Survey, Vol. VIII. By SAMUEL CALVIN, State Geologist. Desmoines, 1897.

This volume embodies the results of field work covering an area of five counties. An important part of the work has consisted in a careful determination of the location and extent of mineral deposits, clays, building stones, and other economic resources, including a valuable discussion of the drift sheets and other surface formations preliminary to a complete description of the soils of the state.

Of great interest to the people of Iowa will be the tabulated statis-

tics, at the beginning of the volume, relative to the year's economic production. The report closes with a paper on the "Properties and Tests of Iowa Building Stones," by H. Foster Bain, which cannot fail to prove of inestimable local value.

Although the directing motive in the work of the survey has been toward economic and practical ends, this report contains, as have preceding volumes, many discussions of general scientific interest. The treatment of strictly geological features, especially in their physiographic aspects, for thoroughness of preparation and clearness of presentation will prove, beyond doubt, to be a source of great interest to the geologists of the country.

The volume is admirably printed, and besides containing many new maps and diagrams, is judiciously illustrated by an expressive collection of photographs in half tone. J. W. F.

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THE

JOURNAL OF GEOLOGY

NOVEMBER–DECEMBER, 1898

BOWLDER-PAVEMENT AT WILSON, N. Y.

Bowlders in till when groupt in an approximately horizontal plane and striated on their upper surfaces in a common direction constitute a bowlder-pavement.[1] Considerable attention has been given to such pavements in Scotland, especially by the Hugh Millers, father and son. In 1859, O. N. Stoddard described a fine example near Miami University, O., but no other American observations have come to my attention.[2] While engaged, last summer, in field work of the United States Geological Survey, I came upon another example, which seems worthy of record.

The village of Wilson is situated about twelve miles east of the Niagara River and half a mile from the shore of Lake Ontario. One of its main streets runs to the shore, where a short pier juts into the lake. There are longer piers a little farther west at the mouth of Twelvemile Creek. On this part of the lake coast the movement of shore drift is from west to east, and this movement is locally obstructed by the piers. West of the piers there is an accumulation of shore drift, and the land gradually encroaches on the lake. East of them the defect of shore drift deprives the shore of its natural protection, and erosion is exceptionally rapid. At the Wilson pier the bluff due

[1] This is the usage of the Scottish geologists. The term has been employed in another sense by J. W. Spencer; see explanation of plate, p. 775.

[2] Diluvial Striæ on Fragments in Situ, by O. N. Stoddard. Amer. Jour. of Sci., 2d Ser., Vol. XXVIII, pp. 227–228.

Unpublisht observations by H. L. Fairchild and M. R. Campbell indicate allied phenomena at Rochester, N. Y., and Cleveland, O.

to the attack of the waves is twelve to fifteen feet high and free from talus, and the section is fully exposed for a half mile to the east. The lower part of the bluff is composed of till, eight to ten feet being visible, and the base not seen. Above this is laminated clay, a deposit spread by the waters of the glacial lake Iroquois.

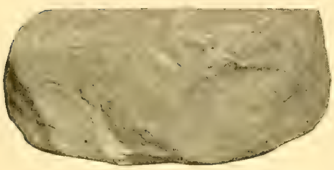
To casual observation the till appears to be a single continuous body, but more careful examination shows that there are two parts separated by a horizontal line between five and six feet above the surface of the water. Both tills are reddish-brown, but there is a slight difference in color, the upper inclining toward orange and the lower toward purple. At various points a bitter efflorescence was seen on the surface of the upper till, and this was not observed on the lower. Both tills are moderately supplied with pebbles and bowlders, the material of the larger fragments being chiefly sandstone and limestone of the subjacent Medina and contiguous Hudson River formations, and ranging in diameter up to about twenty inches. There are also crystalline erratics from a distance, and a few of these are several feet in diameter. Such larger bowlders were not seen in situ in the bluff, but occur here and there on the beach and in shallow water near the shore, where they have evidently been left by the erosion of the enclosing till.

Just at the top of the lower till bowlders are comparatively abundant, and such as are flat lie with their greater dimensions horizontal. Their upper surfaces form parts of a level line drawn across the bluff (Plate XIV), and it was their alignment which drew attention to the compound character of the till. So far as the upper till betrays structure, its lamination is approximately horizontal. Much of the lower till is somewhat definitely laminated, and the lamination is contorted. In some places there are irregular masses of gray till mingled with the red, the general arrangement being suggestive of structures commonly seen in the Archean complex.

Examination showed nearly all the bowlders at the plane of separation to be striated on their upper surfaces. The directions

1

3



2

4

BOWLDER-PAVEMENT

of striation were observed in the cases of ten bowlders in situ, and found to be substantially parallel. Nine ranged between S. 45° W. and S. 50° W., and the tenth was S. 55° W. The accompanying illustrations (Pl. XIV, Figs. 1, 2, and 3) show the upper faces of two of the bowlders and the side of one. It seems clear that after the deposition of the lower till it was over-ridden by a glacier moving toward the southwest. This is the general direction of striation on the bed rock of the region, but no observation was made in the immediate vicinity of Wilson.

All the bowlders strongly glaciated on their upper surfaces were found to have one diameter less than the others, and to lie in such position that the least diameter was vertical. So far as observed, bowlders without pronounced differences in their several diameters were not more strongly glaciated on the upper side than on other sides, although lying at the same level as the others.

To account for these peculiarities, as well as for the accumulation of bowlders at the summit of the lower till, the following explanation is offered: The glacier which deposited the upper till slowly eroded the lower till as it moved over it. When this erosion began to uncover a bowlder, differential pressures resulted. In Fig. 1 the horizontal line represents the upper sur-

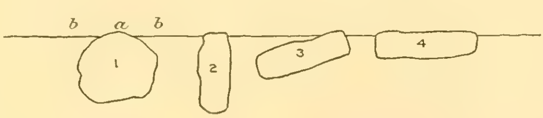


FIG. 1. Diagram illustrating theory of bowlder arrangement.

face of the till undergoing erosion, and 1 the discovered bowlder, projecting above the till at *a*. If the glacier were stationary it would mold itself plastically about this protuberance and press equally on *a* and *bb*, but as it is in motion and has great viscosity, the pressure is greater at *a* than at *bb*, and the differential pressure is not merely momentary, but continuous. It has the effect of a simple pressure on the bowlder at *a*, forcing it down into its plastic matrix, and as the erosion of the till continues,

the bowlder is steadily pusht downward. The erosion is thus rendered selective, the bowlders remaining as the fine material is carried away. The bowlders accumulated at the surface of the lower till are a residuum from the portion of the till which has been removed.

Combined with the vertical pressure at *a* is a horizontal pressure (from forward motion of glacier) tending to rotate the bowlder in its matrix. In the case of a rounded bowlder there may be rotation as long as it continues to be forced downward, but a flat bowlder eventually reaches an attitude of stability. If the longer diameter lies originally vertical or oblique (2 or 3, Fig. 1), there is a partial rotation bringing it to a horizontal position (4, Fig. 1), and rotation then ceases because the differential vertical pressure is applied to both edges of the rock, and any incipient rotation is checkt by increase of pressure on the rising edge. The horizontal attitude is thus stable, and a bowlder having once acquired it retains it as long as the process continues, being thereby enabled to receive thorough glaciation on its upper face.

If this explanation is correct, a bowlder-pavement records an epoch of local till erosion by a glacier. The epoch may be a mere episode interrupting a period of till deposition by the same glacier, or it may be a part of a stage of readvance following a long interglacial period. The demonstration of two tills at the Wilson locality does not by itself constitute an important contribution to the subject of the complexity of glacial history, for the removal of the upper part of the lower till has destroyed whatever evidence may have existed as to the length of time interval separating the two. The significance of the phenomenon can hardly be understood until it shall have been brought into relation with cognate facts from a broad field.

The observation may perhaps serve a more important purpose by directing attention to the possibility of gathering much information as to the direction and history of ice motion from the internal structure of till sheets. The second Hugh Miller not only found a body of information in bowlder-pavements, but

discovered that in certain Scottish and English tills the elongated fragments, large and small, are oriented in the direction of ice motion, so that he was often able from direct examination of the till to determine the direction of the ice current by which it was deposited.[1]

A bowlder-pavement, doubtless continuous with the Wilson, was seen at the lake shore, three miles west of the village, the plane of separation being two or three feet above the water level.

G. K. Gilbert.

EXPLANATION OF PLATE.

Figs. 1, 3. Glaciated faces of bowlders from bowlder-pavement. $\times \frac{1}{7}$.

Fig. 2. Side of the bowlder represented in Fig. 1, showing even truncation of glaciated face. $\times \frac{1}{7}$.

Fig. 4. Till and bluff at Wilson, showing line of bowlders at horizon of bowlder-pavement. Sketch by H. H. Nichols, based on a photograph.[2]

[1] On Bowlder Glaciation, by Hugh Miller, Proc. Roy. Phys. Soc. of Edinburgh, Vol. VII, pp. 156–189, 1884. This paper summarizes earlier literature, and is itself probably the most important contribution to the subject.

[2] The strand is thickly set with bowlders releast from the till by wave erosion. For such accumulations J. W. Spencer, doubtless unaware that the term was preoccupied, proposed the title "bowlder-pavement." In each case the term designates a residuum from erosion, the process being in one case glacial, in the other littoral. It chances the view, drawn to show one kind of bowlder-pavement, illustrates the other also.

GEOGRAPHIC RELATIONS OF THE TRIAS OF CALIFORNIA.[1]

Historical.—Triassic fossils were discovered in California by the State Geological Survey under J. D. Whitney; these were rightly recognized by Gabb[2] as being nearly related to the Upper Triassic Fauna of the Alps, and certain species were even looked upon as identical with European forms. This was the first discovery of marine Trias in the western hemisphere, and the third discovery outside of Europe, the first being that in northern Siberia by Keyserling,[3] the second that in the Himalayas of India, by Strachey,[4] and later described by Salter.[5] Nothing more was done with the Trias in America until the Survey of the Fortieth Parallel discovered it in the Star Peak range of Nevada, where Meek[6] thought he recognized some Californian species. Shortly after this Lower Trias was discovered in southeastern Idaho, by the Hayden Survey, and described by Dr. C. A. White;[7] no Californian species were found here, but this discovery proved the occurrence in the West of a Lower Triassic fauna like that of the Asiatic region.

The next publication on the Californian Trias was by E. von Mojsisovics in *Arktische Triasfaunen*,[8] in which some of Gabb's species are compared with ammonites from Siberia, and the relations of the American faunas to those of the Arctic-Pacific province are discussed.

[1] Published by permission of the Director of the United States Geological Survey.

[2] Palæont. Calif., I, pp. 19–35.

[3] Bull. phys.-math. de l'Acad. Sci. de St. Petersbourg, Tome V, No. 11.

[4] R. Strachey: Quart. Jour. Geol. Soc. (London), Vol. VII, pp. 242–310, 1851.

[5] J. W. Salter (and H. F. Blanford), Palæontology of Niti in the Northern Himalayas, 1865.

[6] Geol. Exp. Fortieth Parallel, Vol. IV, Part I, 1877.

[7] U. S. Geol. and Geol. Surv. Terr., Vol. XII, An. Rep., Part I, 1883.

[8] Mém. Acad. Impér. Sci. St. Petersbourg, VII Ser., Tome XXXIII, No. 6, 1886.

Professor Alpheus Hyatt[1] next undertook a revision of Gabb's work, visiting the original locality and adding largely to the faunal list, and especially to our knowledge of the stratigraphic distribution of the species.

In 1892 the writer's attention was called by Dr. H. W. Fairbanks to a bed of ammonite-bearing limestone near Pitt River in Shasta county; on examination the fossils proved to be of Upper Triassic age. This locality was soon afterwards visited by the writer, who spent the field season of 1893 at work in that region. This work added over fifty species to the known fauna, chiefly of Karnic age, and nearly related to characteristic species from the Tyrolean Alps.[2] The writer has since spent a good part of the field seasons of 1895 and 1898 collecting in that region, and has added greatly to the fossil list, especially of the Ceratitidæ and the Tropitidæ, bringing out even more strongly the relations with the Alpine Trias. A part of these results has already been published.[3]

The latest paper on the Triassic stratigraphy of California is by Dr. E. von Mojsisovics,[4] who, on the basis of communications of Professor Hyatt and the writer, and a suite of fossils sent him by the writer, compares at considerable length the American to the European Upper Triassic faunas.

The accompanying table is based on that published by the writer in *Classification of Marine Trias*, but revised and brought up to date so as to include the stratigraphic work of the past two years, and to give a satisfactory basis for the correlation of marine Triassic sediments for all known regions. Of course it is only tentative, merely the opinions of several men engaged in this study; but the wide distribution of such zone faunas as

[1] Bull. Geol. Soc. Amer., Vol. III, "Jura and Trias at Taylorville, California," pp. 397–400.

[2] JOUR. GEOL., Vol. II, No. 6, 1894, "The Metamorphic Series of Shasta county, California, and JOUR. GEOL., Vol. III, No. 4, "Mesozoic Changes in the Faunal Geography of California."

[3] JOUR. GEOL., Vol. IV, No. 4, "Classification of Marine Trias."

[4] Denksch. K. Akad. Wiss. Wien. (Math. Nat. Kl.), Bd. LXIII, 1896, "Beiträge z. Kennt. d. Obertriadischen Cephalopoden Faunen des Himalayas.

CORRELATION OF MARINE TRIASSIC SEDIMENTS.

Series	Stage	Substage		Zone Fossil	Mediterranean Region	Oriental Region	Arctic-Pacific Region	American Region
BAJUVARIC	Rhaetic		22	*Avicula contorta*	Koessen Beds			
	Noric	Sevatic	21	*Sirenites argonautæ*	Noric Limestone of Hallstadt; Balia-Maden in Asia Minor	*Halorella* beds of the Pamir	*Monotis* beds of Rotti; *Stenarcestes* beds of New Caledonia	*Pseudomonotis* beds ? of Peru; of Queen te Islands
			20	*Pinacoceras metternichi*				
		Alaunic	19	*Cyrtopleurites bicrenatus*				
		Laciacic	18	*Cladiscites ruber*		Himalayan Noric limestone		Swearinger slates, Californian Hosselkus limest'ne
			17	*Sagenites giebeli*				
TIROLIC	Karnic	Tuvalic	16	*Tropites subbullatus*	Sandling beds	Himalayan Karnic limestone	*Daonella* beds of Rotti; *Juvavites* beds of Tonquin, China	with *Subbullatus* and *Trachyceras* faunas; Trias Charlot
		Julic	15	*Trachyceras aonoides*	Raibl beds			
		Cordevolic	14	*Trachyceras aon*	St. Cassian beds			Halobia beds
	Ladinic	Longobardic	13	*Protrachyceras archelaus*	Wengen beds		Nipon beds of Japan	Pitt Shales of Shasta County, California; Star Peak beds of Nevada
		Fassanic	12	*Dinarites avisianus*	Marmolata beds			
			11	*Protrachyceras curionii*	Buchenstein beds			
DINARIC	Anisic	Bosnic	10	*Ceratites trinodosus*	Upper Muschelkalk	*Ptychites rugifer* beds of the Himalayas	*Daonella* beds; Spitzenbergen; Beds of Russkij and Olenek	
		Balatonic	9	*Ceratites binodosus*	Lower Muschelkalk	*Sibirites prahlada* beds of the Himalayas		
	Hydaspic		8	*Stephanites superbus*		Upper *Ceratite* limestone of the Salt Range	*Posidonomya* beds	
SCYTHIC	Jakutic		7	*Flemingites flemingianus*	Zone of *Tirolites cassianus*; Werfen beds of the Tyrolean Alps; *Tyrolites* beds of Djulfa in Armenia	*Ceratite* limestone of the Salt Range; *Subrobustus* beds of the Himalayas	Olenek beds of Siberia	*Meekoceras* beds of ? Idaho; Santa Ana limestone of California
			6	*Flemingites radiatus*				
			5	*Ceratites normalis*				
	Brahmanic	Gandaric	4	*Proptychites trilobatus*		*Ceratite* marls of the Salt Range	Beds of Ussuri and Russkij	*Ceratite* limestone of Inyo County, California
			3	*Proptychites lawrencianus*				
			2	*Gyronites frequens*		Lower *Ceratite* limestone of the Salt Range		
		Gangetic	1	*Otoceras woodwardi*		*Otoceras* beds of the Himalayas		

those of the *Meekoceras* beds of the Lower Trias, of the *Trachyceras* and *Tropites subbullatus* faunas of the Tirolic series, and of the *Pseudomonotis* beds in the Arctic-Pacific region, makes interregional correlation a much easier task.

The nomenclature of the table is that of Diener, Waagen and E. von Mojsisovics,[1] with the exception that *Ladinic* has been substituted for *Noric*, and *Noric* instead of *Juvavic*, the controversy between Bittner and v. Mojsisovics having been settled by a committee of the leading Austrian geologists[2] agreeing to make this change, and by this recommendation being in part accepted by v. Mojsisovics. It is immaterial to American stratigraphers which names are used, but since the Alpine Trias is the type of the marine formation of this age we must use the original formational names given by the Austrian geologists, and in the original sense. It is, therefore, a cause for congratulation that the committee report has been so widely accepted, and for regret that E. von Mojsisovics is still inclined to cling to his new term *Juvavic* for the Hallstadt beds which he formerly called *Noric*.

LOWER TRIAS.

The Santa Ana limestone.—The first Lower Trias recognized in California was found by Dr. H. W. Fairbanks in a hard black siliceous limestone on the west slope of the Santa Ana range, Orange county, California. The fossils were submitted to the writer, and proved to be: a trachyostrachan ammonite, not otherwise determinable, an undetermined brachiopod, and *Pseudomonotis* aff. *clarai*. The ammonite makes the Mesozoic age probable, and the pelecypod makes almost certain the Lower Triassic age, for *Pseudomonotis clarai* is diagnostic for the Werfen beds, upper part of the Alpine Lower Trias. It seems quite possible that this formation in California may be the connecting link between the Mediterranean and the Oriental regions, for the furthest known eastward extension of the Mediterranean Lower Trias,

[1] Sitzungsberichte k. Akad. Wiss. Wien. Bd. CIV. Abth. I. Dec. 1895. Entwurf einer Gliederung der Pelagischen Sedimente des Trias-Systems.

[2] Zur Ordnung der Trias-Nomenclatur. Wien 1898.

that of Djulfa in Armenia, is still of Alpine type, with *Tirolites*? and *Pseudomonotis* conf. *clarai*. The connection that existed in Permian time between India and eastern and southern Europe, through Asia Minor, seems to have been cut off in the Lower Trias. But these faunas are too meager for this to be much more than mere speculation.

	Permian	Lower Trias			Middle Trias	Upper Trias
		Brahmanic		Jakutic		
		Gangetic	Gandaric			
Lytoceratidæ, *Nannites*..........		Himalayas ×				Mediterranean and California ×
Pinacoceratidæ, *Clypites*?.........			Salt Range ×			
Meekoceratidæ, *Koninckites*........		Himalayas ×	Salt Range ×	Salt Range, rare ×		
Meekoceratidæ, *Meekoceras*......		Himalayas ×	Salt Range ×	Mediterranean, Idaho ×	Salt Range ×	
Meekoceratidæ, *Kingites*........		Himalayas ×	Salt Range ×	Olenek and Salt Range ×		
Meekoceratidæ, *Gyronites*?.........			Salt Range ×	Salt Range, Olenek ×		
Ptychitidæ, *Xenaspis*	Salt Range ×	Himalayas ×	Ussuri ×		Himalayas × ?	
Celtitidæ, *Dinarites*				Mediterranean Salt Range Arctic ×	×	
Tropitidæ, new genus.............						

The Ceratite limestone of Inyo county.—In 1896 Dr. C. D. Walcott discovered some ammonite-bearing limestones in Inyo county on the east side of Owens' valley ten miles east-northeast of Lone Pine, two or three miles south of the Eclipse mill,

and about 3000 feet up above the mill, on the trail from Independence ever the Inyo range to Saline valley. The fossils submitted to the writer were badly crushed and distorted, owing to the partial metamorphism that the limestone has undergone, so that they were not in condition for description of genera and species, nor for identification with known species. But the septa permitted the identification of several genera of ammonites with considerable certainty; none of them were higher than the ceratite stage, and some retained simple goniatitic septa, a combination which, in itself, would point to Lower Triassic age, even if all the genera were new. The genera determined were all ammonites, no others being recognizable. The list is given on page 780, showing the range and occurrence of these genera.

In the above list it will be seen that most of the genera are confined to the Lower Trias, or Scythic series, of India, and that while most of them range through the Brahmanic and Jakutic stages, they nearly all reach their greatest development in the Brahmanic, and are rare outside of it. Thus it is probable that the Ceratite limestone[1] of Inyo county belongs to the Brahmanic. Another bit of evidence is the occurrence of some undetermined ammonites not included in the above list, resembling *Otoceras*, which in Armenia occurs in the highest Permian and in the Himalayas in the lowest Trias, only a few feet above the highest *Productus* beds, the top of the Palæozoic.

This fauna is wholly unlike anything in Europe, or indeed anywhere else outside of India, but it resembles that described from the Salt Range by Waagen,[2] and from the Himalayas of India, and Ussuri Bay by Diener.[3] Some years ago it was pointed out by Mojsisovics in *Arktische Triasfaunen* that the Lower Trias of Idaho was closely related to that of the Arctic-Pacific region, although no certain comparison could be made. In the Californian fauna we have the best means of comparison

[1] So-called, because of the prevailing ceratitic type of the ammonites.

[2] Pal. Indica. Salt Range Fossils. Fossils from the Ceratite Formation.

[3] Pal. Indica. Ser. XV. Himalayan Fossils. And *Mém. Com. Géol. St. Petersbourg*. Vol. XIV. No. 3. Triadische Cephalopodenfaunen der Ostsibirischen Küstenprovinz.

with the Indian ammonites, through the monographs of Waagen and Diener. We may, then, assume as certain a connection of the Californian waters with the Oriental region during Brahmanic or Jakutic time, forming the *Arktis* of Mojsisovics, and a separation from the Mediterranean Triassic sea or *Thetys* of Suess. How intimate this connection was we cannot know until material good enough for the identification of species is found.[1]

The danger of inferring separation of provinces on the basis of too few fossils is shown by the following diagram, illustrating the relations of the Lower Trias of the Salt Range with that of the Himalayas, according to Diener.[2]

<table>
<tr><th>Himalayas</th><th>Salt Range</th></tr>
<tr><td>Muschelkalk</td><td>Upper Ceratite limestone</td></tr>
<tr><td>Subrobustus beds</td><td>Ceratite sandstone</td></tr>
<tr><td rowspan="2">Almost unfossiliferous</td><td>Ceratite marls</td></tr>
<tr><td>Lower Ceratite limestone</td></tr>
<tr><td>Otoceras beds</td><td>Unfossiliferous</td></tr>
<tr><td colspan="2">Permian</td></tr>
</table>

The Permian faunas are closely related in both, and that of the Subrobustus beds is, in part, identical with the fauna of the Ceratite sandstone, while between these two horizons each province has unfossiliferous beds corresponding to strata rich in ammonites in the other. It is not, therefore, a justifiable infer-

[1] The writer hopes during the season of 1899 either to visit this locality in person, or to send some of his students there.

[2] Mém. Géol. Surv. India. Ser. XV. Himalayan Fossils. Vol. II. Part I, p. 177.

ence that they were connected in Permian time, and separated after that until Jakutic time.

Tirolites and other members of the Tirolitinæ are conspicuously lacking in the Indian region, and this is true also of the Inyo beds. On the other hand *Dinarites* is entirely lacking in the Lower Trias of the Himalayas, and in the Salt Range below the Ceratite sandstone of the Jakutic, the species described as *D. minutus* Waagen, from the Ceratite marls, having turned out to be a *Ceratites.* And since the Dinaritinæ are known in the Lower Trias of the Mediterranean region, the Inyo fauna seems to have been intermediate between that and the Indian, although much more intimately connected, during the Brahmanic stage, with the Oriental region.

Gabb[1] cites *Goniatites lævidorsatus* Hauer from a locality thirteen miles north of Owens' Lake, from the foothills on the east side of the valley. E. von Mojsisovics[2] says that this ammonite is not Hauer's species, and not even in the same genus with it, *Celtites*, but belong to the group of *Ceratites obsoleti*, subgenus *Danubites*, chiefly characteristic of the Lower Trias. It seems, therefore, that the credit for the discovery of this formation in California must be given to the State Geological Survey under Whitney.

MIDDLE TRIAS

Of the faunal relations of Middle Trias little is to be said, because undoubted fossils of this age are not yet known in the state, nor, indeed, anywhere in America. The writer[3] has described a series of siliceous slates that probably belong in part to the Muschelkalk, but the evidence is merely stratigraphic, the known fossils being too poor to be of any use. The occurrence, at Silverthorn's Ferry on Pitt River, of a number of indeterminable ammonites, one of which resembles *Ptychites*, holds out the hope of future decisive discoveries. It seems likely, too,

[1] Pal. Calif., Vol. I, p. 21.

[2] Arktische Triasfaunen, p. 20.

[3] JOUR. GEOL.; Vol. II., 1894, No. 6. The Metamorphic Series of Shasta county, Calfornia.

that a part of the Star Peak beds of Nevada may eventually be shown to belong here, as Professor Hyatt has long claimed, but as yet the evidence is not convincing.

UPPER TRIAS.

The Upper Trias of the Genessee valley, Plumas county, was discovered and described by the Whitney Survey; its fauna is decidedly Alpine in character, although all the species thought by Gabb to be identical with European forms have since been shown not to agree with them. Since that time Professor Hyatt[1] has visited this locality, and has added greatly to the fossil list, some of the newly discovered ammonites being doubtfully referred to Alpine species.

The Upper Trias of Squaw creek, Shasta county, was discovered by Dr. H. W. Fairbanks, who called the writer's attention to the locality. The writer has since spent a good part of three field seasons in collecting fossils, and in studying the stratigraphy of that region; part of the results of this work has already appeared in the JOURNAL OF GEOLOGY.[2] In the papers referred to the most important species have been listed, although later field and museum study has changed the list considerably, adding many new ones, and dropping several. The fauna contains a large number of *Trachyceras* (subgenus *Protrachyceras*), *Clionites*, *Arpadites*, *Polycyclus*, *Sirenites*, *Tropites*, *Eutomoceras*, *Juvavites*, *Sagenites*, *Nannites*, *Miltites*, *Arcestes*, *Halobia*, etc., of decidedly European type. Dr. E. von Mojsisovics is of the opinion that several of these may be identical with species characteristic of the Tyrolean Alps. The greater part of the fauna belongs to the Karnic stage, zone of *Tropites subbullatus* Hauer, which characteristic ammonite of the Sandling beds is also present in great abundance in the Squaw creek limestone, showing all the varieties known in the Alps.

In the papers cited above the writer has called attention to the occurrence of species *Trachyceras* along with *Tropites subbul-*

[1] Bull. Geol. Soc. Amer., Vol. III, pp. 397–400.

[2] Vol. II, 1894, No. 6; Vol. III, 1895, No. 4; Vol. IV, No. 4, 1896.

latus Hauer, *T. torquillus* Mojs., *T. Telleri* Mojs., and many others characteristic of the Tuvalic substage. In the Hallstadt beds of the Tyrol no such association as this is known; the *Trachycerata* do not occur higher up than the Julic substage, zone of *Trachyceras aonoides*, nor does the Subbullatus fauna appear below the Tuvalic. It is, therefore, a question as to whether the Julic fauna survived longer here than elsewhere, or whether the *Tropites subbullatus* fauna reached here earlier, in middle Karnic time. There is not yet enough evidence to decide this, but it all points to the latter alternative. The *Tropites* fauna is an immigrant fauna wherever known, appearing suddenly without local ancestors in the Alps, the Himalayas, and in California, in the upper part of the Karnic stage; thus it may be that its occurrence in California marks an earlier appearance, for it was probably endemic in the American region. In addition to this, the *Trachycerata* associated with the Subbullatus fauna all belong to the subgenus *Protrachyceras*, which is supposed to be characteristic of a lower horizon than *Trachyceras* itself, which genus has recently been found in the Upper Karnic of the Himalayas. Further, the Subbullatus fauna did not all reach California at the same time, *Homerites semiglobosus* Hauer, not appearing here until all the *Trachyceras* fauna, and most of the *Tropites*, with which it is associated in the Alps, had become extinct.

We have in this occurrence an interesting study in homotaxis; the *Trachyceras* fauna is homotaxial all over the world, so is the Subbullatus fauna, and yet their occurrence together proves that neither fauna was synchronous in its appearance in various parts of the earth, and that even the order of appearance of the two faunas is not the same in all regions.

The most comprehensive review that has appeared on the faunal geography of the Upper Trias is the chapter by Dr. E. von Mojsisovics, "Die Meere der Trias-Periode,"[1] in which all that is known of the distribution and relations of faunas of this period is given, and several pages devoted to the western Ameri-

[1] Denkschriften d. K. Akad. Wiss. Wien, Bd. LXIII, 1896, "Beitr. z. Kenntniss d. Obertriadischen Cephalopoden Faunen des Himalayas."

can Trias, based on the published writings of Gabb, Meek, Hyatt, Whiteaves and the writer, and upon personal communications from Hyatt and the writer. Mojsisovics here takes the view that the occurrence together of the Subbullatus fauna and *Trachyceras* in India and California shows a survival of the latter group beyond its time elsewhere; this is more likely true of India, where the survival consists of single species of genuine *Trachyceras*, but in California the fauna is almost too large to be a survival.

The most interesting fact brought out by a comparison of the Upper Trias of California with that of India and the Alpine Mediterranean region is its near relationship with the latter, most genera and many species being common to the two regions. On the other hand, not many genera and no species are now known to be common to California and India; this is contrary to what we should expect, knowing that during the Lower Trias California was closely connected with India, as shown by community of genera and possibly of species, and also that during this same time neither India nor California was closely connected with the Mediterranean Triassic sea. Great changes in physical geography must have taken place about the end of Lower Triassic time, of which we have a partial record; during the Muschelkalk several species are common to the Indian, the Arctic-Pacific, and the Mediterranean regions, thus showing an opening of connection between regions that before were separated.

This relationship of the Californian to the European faunas persists until after the middle of the Jurassic formation, when the Boreal fauna comes in; towards the end of the Lower Cretaceous the connection with India is again established.

It is hard to see how anyone that has studied the changes of faunal geography undergone by the western American region since Paleozoic time could believe in the permanency of the oceanic basins as they now exist. These shifting faunal relations can only mean rising and sinking of continental margins, cutting off and facilitating intermigration, alternately aiding and obscuring interregional correlation.

JAMES PERRIN SMITH.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. I.

The area of igneous rocks in Eastern Massachusetts, especially in Essex county, has been, as the late Geo. H. Williams said, "more discussed than any other similar region of the continent." But, while it is the subject of a considerable literature, no petrological study of the region has been made. A few investigators, notably Wadsworth and J. H. Sears, have described the rocks, but there has been little or no attempt to coördinate the results and to compare this region with other analogous petrographical provinces, although its resemblance to that of Norway has been noted by Rosenbusch, Brögger and others. It is with the aim of supplying this deficiency that these pages are written.

I have visited the region of Essex county several times and collected a large number of specimens from the various localities, so that my collections are fairly representative of the different types, and my knowledge of their occurrences and relationships sufficient to justify me in undertaking the present investigation. This paper will deal with the subject in a purely petrological way, since the general geological, structural and stratigraphical features are far too complex to be unraveled in occasional visits such as mine were. A number of occurrences of dike and other rocks which merit a more detailed description than is here possible will be published separately, probably, in the *American Journal of Science*.

I would express my sense of deep obligation to Mr. J. H. Sears, of Salem, who has made this region an object of study for many years and whose acquaintance with it is unequaled. He has been most cordial and liberal in giving me specimens which it would have been difficult for me to obtain otherwise, and has encouraged me most generously in undertaking the present investigation.

While the general geology of the region lies outside the scope of the present paper, yet it will be not amiss to give a sketch of its chief features. The igneous rocks of Essex county extend along the coast from Lynn to the New Hampshire line, and inland for a distance of about five to fifteen miles, covering an area of about 342 square miles. To the south igneous rocks of similar character, and probably genetically related, are met with in the Boston Basin, but this paper does not include them. In Essex county they form a long ridge "extending in a northeasterly direction until cut off by the sea. To the northwest and to the southeast of this extended axis we have rocks of a less crystalline character verging upward into distinctly sedimentary deposits."[1] The igneous rocks have broken through and are later than pre-Cambrian and Lower Cambrian strata, blocks of which, often highly metamorphosed, are met with at many points within the igneous area.[2] The igneous rocks are chiefly granites, quartz-syenites, syenites, nepheline-syenites, essexites, diorites and gabbros, cut by numerous dikes, and with later flows of rhyolite. According to Sears[3] these are all pre-Carboniferous. A geological map of Essex county, prepared by Mr. Sears, and published by the Essex Institute in 1893, has lately (1897) been revised by him[4] and will be referred to frequently.

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In the description of the rocks the ideas as to classification generally prevailing in this country will be followed, the age distinction being ignored, and the rocks grouped according to structure and chemical and mineralogical composition. The separation of the dike rocks is largely for convenience and involves no assumptions as to the question of the "Ganggesteine." A number of chemical analyses will be given, and the descrip-

[1] N. S. SHALER. 9th Ann. Rep. U. S. G. Surv., p. 542, 1889.

[2] J. H. SEARS, Bull. Essex Inst., Vol. XXII, 1890.

[3] SEARS, Bull. Essex Inst. Vol. XXVII, p. 112, 1895.

[4] Bull. Essex Inst., Vol. XXVI, 1894, and *ibid*, Vol. XXVII, 1895.

tions will be followed by a general discussion of the results and a comparison of this region with others of similar character.

Granite. — The rocks which belong in this class and which are the granitites of Rosenbusch, have been described by Wadsworth,[1] Shaler[2] and Sears.[3] They are very abundant in the region, covering large areas at Rockport, Gloucester, Manchester, Beverly, Essex and elsewhere, having a general northeast-southwest trend.

The specimens in my possession from these localities are all hornblende-granites containing more or less biotite. The structure is in general typically granitic, a porphyritic development of the feldspar being rare. They are quite coarse-grained, the texture being fairly uniform in the various specimens. Fine-grained forms are less abundant and occur on the borders, as will be described later. In color they are usually light mottled gray (Rockport, west Gloucester, Manchester), but often yellowish (Bay View, Eastern Point), or pink (Wolf Hill, Marblehead Neck), these last two being due to incipient decomposition. The granite of Bass Rock is darker and greenish, forming apparently a transition to the augite-quartz-syenite.

The quartz is often dark and smoky. The feldspars are of the usual light shades, with good cleavage, being salmon-colored only in the specimens from Wolf Hill. Hornblende and biotite are scattered not very abundantly through the mass in black irregular spots. These are the principal minerals seen with the naked eye, but at the quarries of Rockport and elsewhere a large number of accessories have been found, including danalite, fayalite, epidote, zircon, magnetite, apatite, fluorite, and others.

In the area about Rockport pegmatitic veins are not uncommon, made up of coarsely crystalline feldspar and quartz, the latter being occasionally amethystine. The granite, especially of Cape Ann, is largely split by joint planes, and also shows a strong tendency toward rifting. This has been investigated

[1] WADSWORTH, Proc. Bost. Soc. Nat. Hist. Vol. XIX, p. 311, 1878

[2] SHALER, 9th Ann. Rep. U. S. G. Surv., p. 605, 1889.

[3] SEARS, Bull. Essex Inst., Vol. XXVI, 1894.

very fully by Shaler.[1] Judging from the evidence of strain revealed by the microscope the rifting (and possibly the jointing in part) is largely due to dynamic action subsequent to the consolidation of the mass.

In thin sections are seen the following minerals; orthoclase, albite, microcline, hornblende, glaucophane, biotite, pyroxene, magnetite, zircon, apatite, and allanite.

The quartz is highly xenomorphic, being usually interstitial. In some cases (Bass Rock, Rocky Neck at Gloucester) it also occurs in small rounded anhedra, scattered through feldspar areas. A brecciated structure at the borders of the larger quartzes is not rare, and is associated with an undulatory extinction. Mineral inclusions are few, and are only zircons. Gas and liquid inclusions, the latter carrying a movable bubble, are quite abundant though small, and occur in streaks.

The alkali-feldspars are varied and deserve more extended study than the scope of this paper allows. They are chiefly orthoclase and albite, which are almost always intergrown so as to form highly typical microperthites and cryptoperthites. In general they are closely similar to those described by Brögger[2] and Ussing[3] from Norway and Greenland syenitic rocks, and their figures would answer for forms seen here. Cryptoperthitic development is relatively scarce, the majority being perthitic on a fairly large scale. Microcline also is not rare, but less abundant than the preceding. This and the orthoclase are apparently rich in soda. The feldspars are apt to be rather cloudy and dusty with decomposition products, and they often show a brecciated border and undulatory extinction. Inclusions of apatite and zircon are rare. A very little albite-oligoclase is seen in a few sections, showing well-developed twinning lamellæ.

Hornblende, the chief ferromagnesian mineral, is usually xenophorphic, crystal planes being seldom seen. It is in gen-

[1] SHALER, 9th Ann. Rep. U. S. G. Surv., pp. 583–588, 602–605, 1889.

[2] W. C. BRÖGGER, Zeit. Kryst., Vol. XVI, pp. 521–560, 1890, Pls. XXII, XXIII

[3] USSING, Medd. om Grönland, Vol. XIV, pp. 5–101, 1898, Pls. I, II, III.

eral olive-green and highly pleochroic; 𝔠 = dark olive-green, 𝔟 = dark greenish-brown, 𝔞 = yellowish-green. The absorption is 𝔠 > 𝔟 > 𝔞. The extinction angle $\mathfrak{c} \wedge c$ is high, about 29° having been observed in sections cut nearly parallel to (010). In certain specimens, notably those from Eastern Point (Gloucester) and Magnolia, a bluish hornblende occurs not only as separate crystals, but as patches in the green hornblende, and is also found forming a fringe on the ends of large crystals of this mineral. This occurrence is somewhat analogous to that described by Cross[1] in a dike in Colorado, where he regards the blue hornblende as secondary. His dike was much decomposed, while these granites are quite fresh; but it seems probable that here also part of the blue hornblende is secondary. As will be seen later, they are quite common in the region, and in many cases are undoubtedly primary. Inclusions in hornblende are not abundant, a few grains of magnetite, allanite, zircon, and apatite having been seen. The green hornblende often yields a secondary brown biotite on decomposition.

Biotite is a very common constituent, the greater part being primary. The granite near Manchester, represented by specimens from several quarries, is essentially a biotite-granite, hornblende being absent. In the majority of occurrences, however, the biotite accompanies hornblende, and is present in less amount. Two varieties are found. One is very pale green, with rather weak pleochroism, the colors being almost colorless and delicate apple-green. This is probably to be referred to the cryophyllite discovered by Cooke,[2] and investigated by Clarke and Riggs.[3] The other, which is more abundant, is darker greenish-gray, and shows stronger pleochroism; a deep, almost opaque, greenish-gray and a pale olive-green. Sections parallel to the base show in convergent light a marked opening of the optic axes. This biotite is referred to lepidomelane (annite), but Clarke's researches have shown that several varieties exist.

[1] Cross, Am. J. Sci., Vol. XXIX, p. 359, 1890.

[2] J. P. Cooke, Am. J. Sci. (2), Vol. XLIII, p. 217, 1867.

[3] F. W. Clarke, Am. J. Sci. (3), Vol. XXXII, p. 358, 1886.

Both biotites are notable for their poverty in MgO, which will be discussed later. They frequently show signs of alteration, accompanied by the development of magnetite grains, and their laminæ are often bent and distorted.

Secondary biotite occurs in most of the less fresh specimens, of a chestnut-brown color and highly pleochroic. It forms small flakes arranged perpendicular to or in fan-shaped aggregates along the edges of hornblende crystals, of which it is an alteration product. In the granite from the east side of Wolf Hill (Gloucester) are seen small clusters of small biotite flakes of an olive-green color and independent of hornblende, which are probably primary.

Pyroxene occurs in a few of the granites, most abundant in that of Marblehead Neck, though always in smaller amounts than the hornblende or biotite. It is a colorless diopside in stout, columnar, rounded crystals, and shows no noteworthy peculiarity. Occasionally, as at Trumbull's quarry, West Gloucester, it seems to be derived from hornblende, analogously to the often-observed "magmatic" alteration of hornblende in eruptive rocks. In some sections of granites which are not quite fresh the pyroxene is uralitized to some extent.

Magnetite is present in most of the granites, but very sporadically and in extremely small amount. Zircon and apatite are likewise present in most of the specimens, the former being the more common, while apatite is wholly absent in many.

Allanite occurs in granite from a quarry near the Lighthouse on Eastern Point and in that from Marblehead Neck. In the former it is included in hornblende, in the latter in biotite. The sections are rather long, with pointed ends, and the extinctions, either parallel or at angles up to 36°, show that the habit is tabular parallel to *a* (100). The color is deep brown, with strong pleochroism; $\mathfrak{a}$ = light yellowish-brown, $\mathfrak{b}$ = chestnut-brown, $\mathfrak{c}$ = very dark brown; $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. A zonal structure is common, the borders being lighter than the interior. Allanite was first observed in Essex county by D. M. Balch[1] in

[1] Am. J. Sci. (2), Vol. XXIII, p. 348, 1862.

1862 in the granite of Swampscott, was reported from several places in Maine and Massachusetts by Iddings and Cross,[1] while Sears[2] has added a number of localities to the list.

A small grain of pink fluorite was seen in the granite from Squam Light, and colorless grains in that from Pigeon Hill quarry, Cape Ann. I could identify no danalite, which Shaler speaks of as rare and resembling garnet in thin sections.

For chemical analysis a typical fresh specimen was chosen from the large pit of the Rockport Granite Co.'s quarry, a hornblende-biotite-granite; sp. gr. 2.618 at 18° C. There is given for comparison an analysis already published[3] of the riebeckite-granite of Quincy, described by T. G. White.[4]

	I	II		I	II
SiO_2 - - -	77.61	73.93	BaO - - -	....	none
TiO_2 - -	0.25	0.18	Na_2O - -	3.80	4.66
Al_2O_3 - -	11.94	12.29	K_2O - - -	4.98	4.63
Fe_2O_3 - -	0.55	2.91	$H_2O(110°-)$ -	trace	....
FeO - - -	0.87	1.55	$H_2O(110°-)$ -	0.23	0.41
MnO - -	trace	trace	P_2O_5 - -	....	....
MgO - - -	trace	0.04			
CaO - -	0.31	0.31	Sp. Gr.	100.54	100.91

I Hornblende-Granite. Rockport Cape Ann, Anal. H. S. Washington.
II Riebeckite-Granite. Quincy Blue Hills, Anal. H. S. Washington.

The analysis of the Rockport granite is a typical one, fairly rich in potash, but low in lime and iron oxides. It resembles that of the Quincy granite, but the latter is lower in silica and higher in iron oxides. Although the composition of the hornblende is unknown, yet as its amount is small, the mineral composition can be approximately calculated as below in Ia, the biotite being assumed to have the composition $(K_2H_4Fe_4)Al_2(SiO_4)_5$ as given by Clarke from an analysis by Riggs.[5] The composition of the Quincy granite calculated as already published is given in IIa.

[1] Iddings and Cross, Am. J. Sci. (3), Vol. XXX, p. 108, 1885.

[2] Sears, Bull. Essex Inst., Vol. XXVI, p. 189, 1894.

[3] H. S. Washington, Am. Jour. Sci. (4), Vol. VI, p. 181, 1898.

[4] T. G. White, Proc. Bost. Soc. Nat. Hist., Vol. XXVIII, p. 128, 1897.

[5] Clarke, Am. Jour. Sci. (3), Vol. XXXII, p. 360, 1886.

	Ia	IIa		Ia	IIa
Quartz, - -	35.5	30.2	Hornblende, -	2.0	....
Orthoclase, - -	28.2	27.2	Riebeckite, - -	....	12.3
Albite, - -	32.0	27.7	Glaucophane, -	....	2.0
Anorthite, - -	0.5	....	Accessories, - -	0.5	0.6
Biotite, - -	1.3	....			

Micrographic granite.— On reference to Sear's geological map of Essex county it will be seen that surrounding the granite areas and forming a zone between them and the areas of augite-syenite and diorite is a belt of micrographic granite. I have only a few specimens which represent this facies, the best being from Eastern Point, Gloucester, and from near Coy's Pond, Beverly, which were kindly given me by Mr. Sears. These closely resemble the granites, but are dark reddish-brown, finer grained and with less quartz visible. In thin sections they show much the same features as the granites proper. The minerals are the same, but quartz is less abundant. The difference is mainly in structure. In these rocks a micrographic intergrowth of feldspar and quartz is extremely common. The quartz here appears as small rounded spots extinguishing simultaneously in patches in the large feldspars. A similar micrographic structure is described by W. D. Matthew[1] in soda-granite from St. John, N. B. He states, however, that here this structure is best developed in the central parts of the mass and is lost at the edges.

In regard to the composition, while no analysis was made on account of the decomposed condition of the specimens, yet it seems probable, judging from the microscopical examination, that these micrographic granites are intermediate in composition between the granite proper and the augite-syenite, with a silica content of about 70.

Enclosures in granite.— In the granites of Essex county are found in abundance streaks (*Schlieren*) and rounded rock masses of darker color and of finer grain than the surrounding rock, which are also common in granite areas elsewhere. They show

[1] W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 205, 1895.

an evenly granular, granitic structure, varying in texture from moderately to very fine grained and compact. In color they vary correspondingly from light to very dark gray the most compact forms being the darkest. To the naked eye they show the same minerals as the granite, but the ferromagnesian constituents are more abundant. The contact with the surrounding granite is nearly always sharp and clear.

Under the microscope the same essential minerals are seen as in the granite and their habit is much the same, except that all is on a smaller scale. The alkali feldspars are quite similar, hornblende and biotite occur in all cases, the former being generally more abundant. It is usually green and only occasionally shows a bluish hue. In certain rather dark masses from the Pigeon Hill quarry, near Rockport, there is found a peculiar hornblende which occurs in bundles of long slender rods. In color it varies from colorless to pale bluish-gray, the latter shows brilliant polarization colors especially on the edges, and extinguishes obliquely, $\mathfrak{c} \wedge c$ being about 15°. The pleochroism is rather strong, $\perp c$ colorless or pale yellow, $\parallel c$ bluish or deeper yellow-gray, though occasionally it shows no pleochroism. It is apparently a variety of glaucophane. The biotite is also like that of the granites. It is sometimes secondary about hornblende, and in one specimen from Bay View it occurs about magnetite in brown flakes arranged radially. Colorless diopside is not abundant and often shows signs of alteration. Magnetite, while not abundant, is yet more common than in the granite. Zircon is common and in specimens from Pigeon Hill quarry forms well shaped but corroded crystals of considerable size, one being 1.5^{mm} long. Apatite is present as an accessory, but allanite was not observed.

SiO_2	67.35	MgO	0.03
TiO_2	0.60	CaO	0.55
Al_2O_3	15.05	Na_2O	4.42
Fe_2O_3	1.23	K_2O	6.08
FeO	4.76	H_2O (110°—)	0.16
MnO	0.05	H_2O (110°+)	0.17
			100.45

An analysis was made of a rather dark, fine-grained specimen from Pigeon Hill quarry, whose sp. gr. was 2.69 at 17° C. It is notably less siliceous than the granite, contains more iron and lime and higher alkalis, though the ratio of soda to potash remains about the same. From its analogy with the analysis of rocks described below it may be called a quartz-syenite. Owing to the uncertainty of the composition of the hornblende and biotite no exact calculation of the mineralogical composition is possible. A rough estimate gives albite 36, orthoclase 33, quartz 16, hornblende and biotite about 12, and magnetite, etc., 3 per cent.

Akerite (*augitic quartz-syenite*).—The rocks belonging in this class were first noticed by Wadsworth[1] in 1885 and were later described more in detail by Sears.[2] Rosenbusch[3] has expressed the opinion that these are related to the akerite type of syenites, a keen observation which my study of the rocks fully confirms. These rocks are found chiefly in the eastern part of Essex county, in Essex, Beverly, Manchester, Gloucester, and on Cape Ann. They lie between or around the granite areas, are connected with nepheline-syenites on the south, and have a general northeast-southwest trend. They appear to be almost as abundant as the granites.

Although Sears speaks of the megascopic characters as being extremely variable yet all the specimens collected by myself, as well as those given me by him, are fairly uniform. These show a granitic structure and are usually coarse-grained. The color even of the freshest specimens is greenish, which varies in shade from a dark greenish black to a light shade of greenish gray. They weather to a reddish color as Sears observed. The bulk of the rock is composed of feldspar which is of a deep greenish color, often fresh and with glistening cleavage surfaces, at other times dull and waxy. Quartz grains are present in varying amount, some specimens showing considerable while others

[1] WADSWORTH, Geol. Mag., 1885, p. 207.

[2] SEARS, Bull. Essex Inst., Vol. XXIV, 1892, and Vol. XXV, 1893.

[3] ROSENBUSCH, Mikr. Phys., Vol. II, p. 127, 1896.

contain very little, but it is never wholly absent. Black spots of augite are abundant and magnetite is seen here and there.

The microscope reveals the presence of the following minerals: quartz, alkali feldspar, diopside, hornblende, biotite, magnetite, apatite, and titanite. Quartz is not very abundant and is the last product of crystallization, occupying the interstices between the other minerals. It is undoubtedly primary, but the extinction is very often undulatory. The feldspars are mainly microperthitic intergrowths of orthoclase and albite, and resemble closely those of the granite. Microcline is rare. The feldspars are highly irregular as a rule, though some crystal outlines are seen against interstitial quartz. The boundaries between the adjacent crystals are generally zigzag or brecciated, indicating that the mass has been subjected to stresses. Some small albites show beautifully fine and clear twinning lamellæ. As they occur in such brecciated areas they may be supposed to be secondary. The feldspars very commonly show signs of alteration which is evidenced by a cloudy appearance, or when the crystal substance is clear by the cleavage lines and cracks being filled with a greenish decomposition product, the exact nature of which could not be determined.

The pyroxene occurs in scattered crystals of irregular outline. It is nearly colorless or a pale greenish-gray, without pleochronism but with high extinction angles. It is not infrequently uralitized on the edges, and carries inclusions of magnetite, apatite, and titanite. Primary hornblende of deep green or brownish colors is common in some specimens, notably in those from Poorhouse Hill, Beverly, and Cape Pond, Rockport. This is also intergrown with the pyroxene in parallel positions. Biotite is extremely rare or entirely wanting in these rocks, and when present is almost certainly secondary. Magnetite and apatite, occasionally in very long needles, are more common than in the granite. Zircon is present but is less abundant. Colorless titanite is quite common, usually in almost square sections with oblique extinctions. No nepheline was to be found in any of my sections, although Sears notes its presence. Its occur-

rence with quartz would be certainly very anomalous. Aegirite also, mentioned by Sears, was wanting in the material examined by me.

An analysis was made of a nearly fresh, typical specimen collected from a newly blasted mass on Prospect street, Gloucester. It is neither extremely light nor extremely dark in color, and seems to be an average sample of these rocks. Its sp. gr. was 2.612 at 17° C. For comparison there is given in II the analysis of an acid akerite from Norway.

	I	II		I	II
SiO_2	66.60	66.13	MgO	0.36	0.04
TiO_2	0.76	0.74	CaO	2.21	0.81
Al_2O_3	15.05	17.40	BaO	none	....
Fe_2O_3	1.07	2.19	Na_2O	4.03	5.28
FeO	4.42	....	K_2O	5.42	5.60
MnO	trace	0.13	H_2O	0.41	1.22
				100.33	99.54

I Akerite. Prospect street, Gloucester. H. S. WASHINGTON, anal.

II Akerite (porphyritic). Between Thinghoud and Fjelebua, Norway. MAUZELIUS, anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 46, 1890.

It will be seen that this analysis, which closely resembles that of the enclosure in granite, except the higher lime, is essentially that of a basic granite or an acid syenite. In this case I adopt Brögger's scheme of classification,[1] and consider that the limit between the syenites and the granites lies at the silica content of the prevailing feldspars, which are here orthoclase with about 66 per cent. and albite with about 68. These rocks, therefore, I would class with the quartz-bearing augite-syenites, in accordance with Wadsworth, Sears and Rosenbusch.

That the rock belongs to an alkali magma is evident from its high alkali content ($K_2O + Na_2O = 9.45$), and its close parallelism with the *more acid* of Brögger's akerites is shown by comparison with the analysis in II. It must be noted, however, that this is an extreme type, and that the akerites as a group are more basic. Probably some of the darker and presumably

[1] BRÖGGER, Zeit. Kryst., Vol. XVI, p. 55, note, 1890.

more basic specimens, such as one from the railroad cut just north of the Manchester station, would correspond to them. The rather high lime is to be noted, but this is used up in the formation of pyroxene, leaving none for lime-soda feldspar, which, as the microscope shows, is not present.

Nordmarkite (*mica-hornblende-quartz-syenite*). — In Shaler's geological map of Cape Ann[1] there is indicated on both sides of Squam River an area of igneous rock, which is called diorite. Sears,[2] after a careful study of all the occurrences, came to the conclusion that they are not diorite but "phases of the augite-syenite rock," an opinion in which I concur. These rocks are far more limited in their distribution than the preceding, being found chiefly in Shaler's "diorite" area in West Gloucester and along the Squam River. I have specimens also from Hospital Point, Beverly, and from Salem Neck. They are light-gray fine-grained rocks, of granitic structure, looking like fine-grained diorite, composed of a white mass of feldspar, with subordinate quartz, thickly sprinkled with black specks of biotite and hornblende. The specimens from Hospital Point and Salem Neck are porphyritic through the presence of rectangular feldspar phenocrysts, from five to ten millimeters in length, and a few small quartzes.

They show under the microscope a granitic structure, though the quartz is less apt to be interstitial and usually forms small rounded spots in the feldspars, but is not pegmatitic as in the micrographic granite. The feldspars are alkali-feldspars, but do not show much tendency to microperthitic intergrowth. For the most part they are orthoclase or soda-orthoclase in simple crystals or Carlsbad twins. Albite is present in smaller amount, showing fine twinning lamellæ, with the extinctions proper to that mineral. In the specimens from Shaler's "diorite" area biotite is almost the only colored constituent. It forms small brown or greenish-brown, strongly pleochroic flakes, which are only rarely altered at the borders with development of magnetite grains. A

[1] SHALER, 9th Ann. Rep. U. S. G. Surv., Pl. LXXVII, 1889.

[2] SEARS, Bull. Essex Inst., Vol. XXV, 1893.

green hornblende is rare in these specimens and pyroxene seems to be entirely wanting. Magnetite, apatite and zircon are present in small amount. Aegirite, spoken of by Sears as often present, was not seen by me.

The specimens from Hospital Point and Salem Neck resemble these as far as the quartz and feldspars go, though these are finer in grain and microcline is more abundant. The biotite is also identical. A fresh, primary, greenish-gray pleochroic hornblende is abundant. Both minerals are much corroded. Magnetite and apatite are more abundant, zircon in about the same amount. These rocks are apparently transition forms toward a more basic variety, represented by specimens from Concord street, West Gloucester and from several points south of Shaler's area. The latter are darker in color, due to greater abundance of biotite and hornblende. They are like those just described in thin section except that there is less quartz, and hornblende and biotite are more abundant, the former predominating. While no plagioclase or nepheline was seen, they seem to be connecting phases with the diorites and essexites of the region near them.

For the analysis representing these quartz-syenites a specimen was chosen from the west end of Wolf Hill, northwest of Gloucester, which, although not far from the granite, was fresh and seemed to be representative of the rocks of Shaler's area. For comparison is given an analysis of nordmarkite from Norway.

	I	II		I	II
SiO_2	68.36	64.02	CaO	1.85	1.00
TiO_2	trace	0.62	BaO	....	....
Al_2O_3	16.58	17.92	Na_2O	3.97	6.67
Fe_2O_3	0.90	0.96	K_2O	5.27	6.08
FeO	3.24	2.08	$H_2O(110°-)$	0.18	....
MnO	trace	0.23	$H_2O(110°+)$	0.17	1.18
MgO	0.45	0.59			
				100.97	101.37

I Nordmarkite, Wolf Hill, Gloucester. H. S. WASHINGTON anal.

II Nordmarkite, Tonsenaas, North of Christiania. JANNASCH anal. BRÖGGER, Zeit. Kryst., Vol. XVI, p. 54, 1890.

The close resemblance of this analysis to those of the granite enclosure and the akerite is evident, the main difference being in the silica, while, like the akerite, it is richer in CaO and MgO than the enclosure. It also closely resembles the analysis of nordmarkite from the Christiania region, although rather more acid and with less alkalies. Since it corresponds to these in mineral composition the name of nordmarkite is justified, especially as the akerites are a more basic group, while the nordmarkites are essentially more acid in their characters and affinities. It may be noted *en passant* that here also, as in so many cases elsewhere, we meet with biotite and hornblende occurring in the more acid, while pyroxene occurs in the more basic, members of the same series.

Nepheline-syenite. — The rocks belonging here, first noticed by Streeter, have been described by several petrographers, of whom may be mentioned Kimball,[1] Wadsworth,[2] Sears[3] and Rosenbusch.[4] They are not abundant in the region and are confined to an area along the coast about eight miles long and much less wide, extending from Salem Neck to Gale's Point, Manchester, and including the islands in and near Salem Harbor.

These rocks, as is usual, are prone to variation so that there is much variety among the specimens, even from the small area of Salem Neck. Structurally they may be divided into two groups, a granitic and a trachytic, which correspond to the ditroite and foyaite of Brögger.[5] One or two representatives of Brögger's laurdalite-structure were found, but not in typical development. While the two main structural types shade into one another the foyaitic seems to predominate, or at least there is a strong tendency to foyaitic development.

The ditroites from Salem Neck, Great Haste Island and Mackerel Cove are not very coarse-grained rocks, of dull gray

[1] KIMBALL, Am. Jour. Sci. (2), Vol. XXIX, p. 67, 1860.

[2] WADSWORTH, Geol. Mag., 1885, p. 209.

[3] SEARS, Bull. Essex Inst., Vol. XXIII, 1891.

[4] ROSENBUSCH, Mikr. Phys., Vol. II, p. 185, 1896.

[5] BRÖGGER, Zeit. Kryst., Vol. XVI, p. 39, 1890, and also ERUPTGEST, der Krist. geb., Vol. III, p. 165, 1898.

color and granitic structure. The feldspar is white ; nepheline gray or brownish, with occasional yellow or gray cancrinite and blue sodalite which is abundant in certain veins on Salem Neck and elsewhere. Biotite, hornblende and aegirite are common, but are very irregularly distributed. Often they are scattered uniformly through the mass, but again they are rare or else abundant, and any one may predominate to the exclusion of the others. Occasional small brown crystals of zircon are seen, often of some size, but it never rises above the rank of an accessory, so that the name zircon-syenite, which has been applied to these rocks is quite unjustified. Magnetite is not uncommon, sometimes in large grains, and pyrrhotite is seen in one specimen.

In thin section the feldspars, chiefly albite and orthoclase, show less tendency to microperthitic intergrowth than in the granites, though such are not rare. The orthoclase is frequently in Carlsbad twins, and the albite shows twinning lamellæ, but both are found in simple crystals. Microcline, spoken of by Rosenbusch as abundant, is rare in my sections. The nepheline calls for no special comment. While usually interstitial between the feldspars, small, stout prisms are often included in them. Sodalite is rare in the sections. In the rock from Mackerel Cove and from Great Haste Island it occurs decomposed to a dull, fine-grained aggregate (*Spreustein*) interstitial between the feldspars. This decomposition has taken place while the nepheline has remained perfectly fresh. Cancrinite, colorless in thin sections, was observed in the syenite from Salem Neck in small amount, but elsewhere was rare. It was identified by its cleavage and high birefringence.

Perhaps the most common of the ferromagnesian minerals is a deep brown, highly pleochroic biotite, which forms thick plates or stout prisms. An olive-green biotite also occurs on Salem Neck, but is much less common. Hornblende is not very abundant, except in the foyaites of Salem Neck. It is greenish-brown, or a deep olive-green, and highly pleochroic, and much resembles the aegirite. In a few cases it occurs as a border around

aegirite. The pyroxenes are represented by a very pale, greenish-gray aegirite-augite ($\mathfrak{c} \wedge c = 34°$) and by green aegirite. The former occurs in quantity only in one specimen from Salem Neck with biotite. The ægirite is abundant in many sections, often in those free from biotite. It is clear grass-green, with strong pleochroism: $\mathfrak{a}$ = deep grass-green, $\mathfrak{b}$ = grass-green, $\mathfrak{c}$ = light greenish-yellow. The extinction $\mathfrak{c} \wedge c$ is about 7°.

Titanite, magnetite, and zircon are rare; apatite occurs in patches, but is not common. No eudialyte was seen. A few grains of a yellow, strongly pleochroic mineral, referred to laavenite, were found.

	I	II	III
SiO_2	58.77	59.31	60.39
TiO_2	0.31	0.32	....
ZrO_2	0.11	....	....
Al_2O_3	22.64	22.50	22.51
Fe_2O_3	1.54	1.93	0.42
FeO	1.04	1.40	2.26
MnO	trace	trace	0.08
MgO	0.19	0.17	0.13
CaO	0.74	0.46	0.32
BaO	none	....	....
Na_2O	9.62	7.98	8.44
K_2O	4.89	4.08	4.77
$H_2O(110°-)$	0.07	0.15	....
$H_2O(110°+)$	0.90	1.12	0.57
	100.82	99.42	99.95

I Nepheline-Syenite. Salem Neck. H. S. Washington anal.

II Nepheline-Syenite. Great Haste Island. H. S. Washington anal.

III Litchfieldite. Litchfield, Maine. L. G. Eakins anal. BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 241, 1892, contains trace of CO_2.

The foyaites show their structure in the hand specimen very clearly, most surfaces exhibiting a multitude of long, glistening cleavage surfaces of feldspar, arranged in parallel position, forming a sort of flow structure. Surfaces in one direction, however, are made up of flat isometric feldspar plates, owing to the tabular development of the crystals parallel to *b* (010). They are clear ash-gray, and not very fine grained. In thin section they

differ from the preceding chiefly in the structure, which is eminently trachytic. The minerals are much the same, and the feldspars differ only in habit.

Two analyses of the nepheline-syenites were made, one of a specimen from Salem Neck west of the Fort, which was collected on the excursion of the A. A. A. S. in August 1898, under the guidance of Mr. Sears ; the other of a specimen from Great Haste Island, given me by that gentleman. The former is foyaitic in microstructure, the latter more ditroitic. Both are apparently quite fresh. Analysis III, of litchfieldite, is introduced for comparison.

The two analyses resemble each other very closely, except that the former has more soda and less iron oxides. Compared with nepheline-syenites from other regions, the Salem rocks are notably poorer in lime and magnesia, and rather higher in silica than most. In these respects they correspond closely to the nepheline-syenites of Litchfield, Maine, and Red Hill, New Hampshire, described by Bayley,[1] especially the former. This is an extremely albite-rich type, to which he has given the name of Litchfieldite. Bayley regards the orthoclase as secondary for the most part, but it is to be observed that, even if it owes its present form to secondary processes, it must have existed in the original rock. Although the composition of the ferromagnesian minerals in the Salem rock is not known with certainty, yet a rough estimate may be made of its mineralogical composition. This is given in **Ia,** the composition of the Litchfield rock as calculated by Bayley from good data being given in **IIIa.** It will be seen that there is much similarity between the two.

	Ia	IIIa		Ia	IIIa
Albite - - -	43	46.9	Lepidomelane - -	..	6.9
Orthoclase - -	27	27.0	Biotite, etc. - -	6	...
Nephelite - -	20	17.0	Zircon, Magnetite, etc.	3	...
Cancrinite - -	1	2.0			

Pulaskitic Syenite.—In connection with the nepheline-syenites, and constituting a facies of them, are found rocks which

[1] BAYLEY, Bull. Geol. Soc. Amer., Vol. III, p. 231, 1892.

are either extremely poor in, or quite wanting in, nepheline. These are true syenitic rocks and among my specimens two main varieties may be distinguished. They shade into the preceding group by imperceptible gradations.

The first is found at a quarry on the north shore of Salem Neck, west of the Fort, and is essentially a border facies near the contact with essexite, which crops out close by on the other side of a small hollow. This is typically foyaitic (trachytic) in structure and shows the tabular feldspars and their parallel arrangement. A variety of this, met with farther east near the water's edge, is brownish and porphyritic through the presence of abundant feldspar tables strewn irregularly in a feldspathic groundmass. These syenites resemble the foyaites in all essentials, except that nepheline is absent and the feldspars are nearly always microperthitic. The colored minerals are olive-green hornblende, brown biotite, and green aegirite, all in about the same amount. Magnetite grains and an occasional apatite needle are also found.

This rock corresponds closely, both in evident structure and mineral composition, to the hedrumite of Brögger[1] from the laurdalite region, and which he defines as: "nepheline-poor to nepheline-free syenitic rocks with trachytic structure exactly corresponding to that of the foyaites." Since, however, its analysis (I) shows that it is decidedly more acid than Brögger's analysis of hedrumite, it would better be classed with the pulaskites.

The other type of syenite forms coarse-grained masses and veins in the nepheline-syenite, and is best represented by a specimen from Salem Neck given me by Mr. Sears. This shows a coarse-grained mass of pearly, tabular, alkali-feldspar crystals, arranged in radiating groups, with a little aegirite, etc., in black grains and a minute amount of magnetite. Under the microscope the feldspar tables are seen to be microperthite, though kryptoperthite is also seen, as well as albite alone, showing fine and clear twinning lamellæ. There is possibly a slight admix-

[1] BRÖGGER, Zeit. Kryst, Vol. XVI, p. 40, 1890. It is more fully described later in Erupt. gest. d. Krist. geb., Vol. III, pp. 183 ff., 1897.

ture of the anorthite molecule. The only colored component seen in the sections is a grass-green aegirite, but other ferro-magnesian minerals are probably present. The large crystals are well shaped, but have borders of detached aegirite grains which are embedded in the surrounding feldspar. These grains extinguish simultaneously with each other and with the large crystal, forming a sort of pegmatitic zone. The aegirite has been apparently cariously corroded by the magma and the hollows filled with feldspar substance. Nepheline occurs very sparingly in small interstitial spots.

An analysis of this type yielded the results below, in II :

	I	II	III	IV
SiO_2 - - -	63.71	63.09	64.54	63.71
TiO_2 - -	trace	0.45	trace	0.86
ZrO_2 - - -	....	0.06	....	....
Al_2O_3 - -	18.30	18.50	18.13	16.59
Fe_2O_3 - -	2.08	2.90	2.63	2.92
FeO - -	2.52	1.36	0.97	0.66
MnO - - -	trace	trace	....	0.20
MgO - -	0.09	0.16	0.67	0.90
CaO - - -	1.18	1.00	0.62	3.11
BaO - -	....	....	0.42	....
Na_2O - - -	6.39	7.25	6.60	8.26
K_2O - -	6.21	5.23	5.99	2.79
$H_2O(110°—)$ -	0.09	0.21	....	....
$H_2O(110°+)$ -	0.17	0.62	0.31	0.19
P_2O_5 - - -	....	....	trace	....
	100.74	100.83	100.88	100.19

I Pulaskite (hedrumitic). Salem Neck. H. S. WASHINGTON anal.
II Pulaskite. Salem Neck. H. S. WASHINGTON anal.
III Pulaskite. Farisvand. BRÖGGER. Erupt. gest. Krist. geb. III, 198. 1898.
IV Umptekite. Bank of the Umpjaur. Kola Penin. Finland. ROSENBUSCH. Elemente d. Gesteinslehre. 1898, p. 112. No. 5.

It is decidedly more acid than the normal type, carrying less alumina, a little more lime, and about the same amount of alkalis. It is evidently a rather acid syenite, but its real affinities are uncertain. It bears a resemblance to the umptekite which Ramsay observed on the borders of the nepheline-syenite of Kola, and it is of interest to note that Rosenbusch speaks of

umptekites occurring at Curtis' Point, Beverly, and other localities of the Massachusetts region, and also refers the nepheline-syenite of Red Hill, N. H., to this type.[1] The umptekites, however, are typically soda-hornblende rocks, and markedly higher in lime and magnesia, as seen in analysis IV. They certainly show greater analogies with the pulaskites as defined by Brögger: "Nepheline-poor to nepheline-free rocks, also quartz-free or very poor in quartz, poor in dark minerals and with eugranitic structure, in which a development of the feldspars with rectangular or long rectangular sections predominates." It is of interest to observe also the affinity with the albite-rich litchfieldite. A rough calculation of the analysis II gives albite about 58.5 per cent., orthoclose about 31.5, anorthite about 2, and the rest (8 per cent.) colored minerals and magnetite. This rock, then, may be called a pulaskite, or rather a pulaskitic phase of the nepheline-syenite. It must be borne in mind, however, that both this and the hedrumite are only facies of the main foyaitic mass, and not independent rock bodies, at least so far as is yet known.

Orbicular syenite.—A small but interesting type of syenites is found near Bass Rock, Gloucester, and also, according to Mr. Sears, at Salem Neck, Beverly, and on the Manchester Shore, the development being in all cases quite local. Near Bass Rock, the only locality examined by me, it occurs as rounded inclosures in an outcrop of granite, apparently in place, together with similar masses of a dark, coarse-grained dioritic rock, which will be described later. A narrow compound dike of aplite cuts the granite and its inclosures. Of the occurrence of Mr. Sears' specimens I have no data at hand. The syenites are fine-grained and compact, with a groundmass of a light-gray color. Scattered through this are phenocrysts of black hornblende some 0.5 c.m. long, each hornblende being surrounded by a narrow zone of white, finely granular feldspar. These small areas of black with white borders give a peculiar orbicular appearance to the specimen.

[1] Cf. ROSENBUSCH, Elemente d. Gesteinslehre. 1898, pp. 113.

Under the microscope the groundmass is seen to be finely granitic in structure, and to be composed largely of alkali feldspar in xenomorphic grains, microperthite being rare, with only an occasional plagioclase grain. There are also present, somewhat abundantly, small, clear, rectangular sections of orthoclase. A little quartz occurs, especially as small interstitial grains. Irregular anhedra of colorless or very pale greenish-gray diopside are scattered through the groundmass. These are often surrounded by a zone of green or bluish-green pleochroic hornblende, which does not seem to be secondary. Magnetite grains, often surrounded by an amphibole halo, are not uncommon, and small apatite needles are met with.

The large black spots consist essentially of an olive-green, slightly pleochroic, hornblende. These hornblende areas are not continuous, but are made up of more or less rounded spots of hornblende, between which lies a granitic mesostasis of feldspar grains like the groundmass. The small hornblende spots in each area have their cleavage cracks parallel and extinguish simultaneously, so that the structure is micropoikilitic. The white borders are of granular feldspar, free from pyroxene, in which the small rectangular orthoclase sections seem to be more common. They pass insensibly into the surrounding groundmass.

A specimen given me by Mr. Sears from Salem Neck (?) is similar, but the structure of the groundmass is more trachytic, the pyroxene is largely replaced by dark green biotite, and the hornblende phenocrysts are much darker in color. The orbicular spots are quite ophitic in structure, owing to the tabular development of the feldspars. No analysis of these rocks has yet been made.

HENRY S. WASHINGTON.

(To be Continued)

THE GENETIC CLASSIFICATION OF GEOLOGICAL PHENOMENA.

In the consideration of every branch of natural knowledge, one of the first phases to receive attention is some ready means of comparing the various phenomena presented. Gradually there grows up some systemization of the facts and principles, that afterwards reflects the particular stage that the branch at that time attained. This orderly arrangement is the initial step in raising the branch to the dignity of a science.

Scientific advancement may be measured by the degree of taxonomic completeness shown, and by the character of the criteria regarded as critical. As progress is made a rapid evolution in the fundamental plan of grouping the facts takes place. In the beginning, a classification, crude though it may be, is outlined from those superficial features that, at first glance, are the most striking. This is, at a later stage, modified to one in which similarity of common characters, irrespective of natural relations, is taken into account. A vastly more advanced conception is classification based upon affinity, in which for similarity of features is substituted similarity of plan. The final stage is one in which origin, or causal relationship, is the governing principle. This is genetic classification.

At the present time the science of geology is just entering upon the stage last mentioned. As yet, no complete genetic scheme has been proposed. However, various attempts have been made to emphasize the principle of genetic association. All of these efforts appear to be too closely wrapped up in the older conceptions to show very much real advancement over them. They plainly indicate that the time is now ripe to seriously plan for a purely genetic arrangement of geological phenomena.

The older text-books on geology treat of all things geological

from the standpoint of the finished products. The idea that the latter are the visible expressions of many and constantly changing agencies has received only indirect or secondary practical consideration. As a result the production of many, if not most, geological features are loosely, or in a very vague way, ascribed to causes that are very complex. That is, instead of being single and simple the ascribed agencies are in reality a combination of several very distinct causes. For example, rock weathering is usually spoken of as if it were a single process in operation; whereas it involves the action of at least three distinct forces, one of which is strictly physical and the other two chemical, that are called into play separately or in conjunction.

So far as concerns the standpoint of treatment, the newer text-books on geological science are not much of an improvement over the older ones. The antiquated plans of making the products all important and of not distinguishing between processes still thoroughly permeate them. In some cases a little more space than formerly is devoted to "dynamical" geology, and a little less stress is placed upon the so-called historical section. Otherwise, there is relatively small difference between the geological manuals of today, and those of a quarter or a half century ago.

At this time it is not quite clear just what are the real reasons for this lagging of the manuals so far behind the science itself. Not the least important factor probably is that, as a rule, the makers of popular text-books are not in a broad way creative or productive investigators. The advance movement in geology began nearly a score of years ago, and today it is quite generally appreciated by all active workers, who face the subject in nature.

While it was only natural that geology should finally come to be placed upon a strictly genetic, or philosophic, basis, it was due primarily to the modern geographic school that the first strong impulses in this direction were given. The geographers, however, have not developed their side of the subject in as purely a genetic manner as they would have us believe, or as their opportunities permit. They certainly began in the right way, but in

the multitude of new conceptions and the maze of geographic forms that were presented, the analysis of the simple processes that were continually at work was largely overlooked.

So far as I am able to see, Gilbert appears to be the only one who has yet struck the right chord in the attempt to classify, by the processes, geological phenomena. As long ago as 1884 this writer proposed a " Plan for a Subject Bibliography of North American Geology," in which the geological agencies, instead of products are given primary consideration. How far the scheme would have been developed had it been allowed to go on cannot now be inferred. Since that time nothing further has been done in regard to this matter. The arrangement, presenting partly the common subdivisions of the subject of geology as given in our text-books, indicates that the author did not have in mind a classification that can be regarded as strictly genetic.

A few years later McGee suggested "a purely genetic taxonomy of geology, designed to include geography." This plan is particularly instructive as illustrating another phase of the subject. A critical examination of the scheme clearly shows that it is not really genetic except in name. Each product is made to have a constructive and a destructive phase. This plan has been, it may be here mentioned, seized with avidity by the more progresssive geographers. Its method is particularly attractive when applied to topographic forms, especially since it has been fully recognized that they all have "life histories." It is manifest, however, from the whole treatment of the theme that this plan has for its actual foundation the product and not the process. Stages of construction and of destruction must necessarily center around the feature and not the agency producing it. The essential characteristic of this scheme is the twofold nature of the production of every geographic form. When it is remembered that in the old geology the product is the all important factor, and in the new the process, it is at once seen that the dual plan is based entirely upon the old conception, and that the truly genetic principle is lost.

The plans of classification by genesis that have been formu-

lated by the geographers have to be made much more comprehensive than they now are, before they can accomplish their intended service. To begin with, an adequate scheme should be based directly upon geological agencies. Topographic features are largely only the outward expressions of the internal arrangement of the earth. The two groups of characters should be paralleled. One represents form — the physiognomy; the other structure — or anatomy. Yet some geographic features have no measurable equivalent in structure; and many structures do not give rise directly to distinctive forms of surface relief.

In a strictly genetic arrangement, where the processes and not the products are made the central theme, the continual operation of two antagonistic forces does not really exist. Constructive and destructive agencies can be recognized only when the phenomena are made the basis of the scheme. Processes are merely operative. If coupled with the products at all, in classification, all must be regarded as formative or constructive. The product's destruction, its loss of identity, is wholly immaterial. The action of agencies is merely to produce constant change.

A truly genetic scheme for the classification of natural phe nomena thus always has prominently presented its underlying principle of cause and effect. All products must find accurate expression in terms of the agencies. Only then are the broader distinctions in geological classification rendered possible. The various taxonomic groups are made separable only when it is recognizable how, or in what manner, the component parts of the materials dealt with are influenced. Under one set of agencies and conditions a rock-mass is affected in one way, and the component units act altogether differently from what they do under another set of agencies. The primary groupings of the geological processes must be based, therefore, upon the manner in which these agencies affect the rock materials.

When rocks, or the materials with which geology has to deal, and through the medium of which geological phenomena take definite form, are carefully considered with reference to

their behavior under different physical conditions, it is found that, broadly speaking, they are acted upon in four very distinct ways: (1) In a most comprehensive manner all the rocks of the globe act as a unit, and are affected as such by only the cosmical forces. They are then considered in their astral relations. (2) Again, physical forces may affect rocks as great bodies, masses or formations. This may be regarded as their corporeal aspect. (3) Rocks may also be influenced only as particles. They are then treated of in their molar relations. (4) Finally, rocks are changed by the motions of their molecules and atoms. The molecular agencies, as understood in this connection, are those commonly termed physical (in its most limited sense) and chemical. Since, for geological purposes, it is hardly necessary to make any distinction between the two processes of this class, both are called molecular.

Each of the main groups, or kinds of geological processes, has its several minor categories, and each of these its particular phases. Activity of the subordinate agencies as comprehended under the latter give rise to the various classes of geological structure and geographic form.

While a complete arrangement of all geological phenomena, according to the plan suggested, would necessarily require a critical inquiry into the whole subject of geology, some of the principal features of such a genetic scheme may be indicated by the accompanying outline.

From this arrangement may be readily inferred many of the shortcomings of our existing systems. Two points are also prominently brought out. One is the frequent origin of very similar products through the action of diverse processes. The other is the complicated nature of most of the agencies that we commonly regard as simple. The absolute necessity is thus shown for a new series of brief, self-explanatory terms that will enable us to express with exactness the various processes according to the modern view or modified conceptions.

In enumerating some of the chief processes affecting the rocks a number of familiar terms do not appear. Among these

CLASSIFICATION OF GEOLOGICAL PHENOMENA BY GENESIS.

Processes (Geodynamy)			Structures (Geotectonics)	Forms (Geography)
Kind	*Category*	*Phase*		
Astral (*as a unit*)	Refrigeration		Rock	Envelopes
	Revolution	Climatic		
	Rotation	Eolic Hydric Lithic		Trade winds Ocean currents Geosphere
	Gravitation	Depressive Repulsive	Epeiroclines	Continents, oceans Tides
Coporeal (*as masses*)	Diastrophism (Solid)	Plicative Fractural Displacive Fissile Fluent Comminutive	Flexures Joints Faults, thrusts Cleavage, fissility Schistosity Brecciation	Mountain ranges, great lakes, and seas Salients Fault scarps
	Vulcanism (Liquid)	Intrusive Effusive Explosive	Dikes, veins, silts, necks, laccolites, basics, etc. Lave sheets Ash beds	Ridges (some), peaks, domes, etc. Mesas, lava fields Cones, craters
Molar [Physical] (*as particles*)	Seismism			
	Cementation	Compressive		
	Disintegration	Frigidic Caloric Biotic		Regolith, talus slopes
	Gradation	Eolic Glacic Hydric	Stratification	Dunes, sand ridges, etc. Moraines, drumlins, kames, drift-plains, basins, some lakes; Coastal plains, peneplains, flood plains, deltas, valleys, drainage systems, etc.
	Automotion	Vital Anthropic		Coral reefs, shell-banks, etc. Mounds, etc.
Molecular, or chemical. (*As molecules and atoms*)	Decomposition		Fissures (some)	Sinks, caverns, etc.
	Induration			Crags, reefs, water falls (some)
	Metamorphism	Paramorphic Metasomatic		
	Mineralization		Mineral veins (some)	
	Precipitation			

may be mentioned, for examples, weathering, erosion, deformation, transportation, and deposition. These are names that, as technical terms, do not now mean very much. While they are commonly used, and perform useful functions in certain cases, they really indicate an imperfect state of knowledge of the subject, or rather remissness in careful discrimination. All are compound processes, and involve the simultaneous action of several distinct agencies. Weathering includes, among other changes, the mechanical breaking down of rock-masses through the effects of heat and cold, the action of life or the application of pressure (disintegration); it involves the chemical alteration of some of the essential constituents, by which the identity of the rock-mass is lost (decomposition); and it also embraces, in its earlier stages, chemical change in which traces of the identity of the original rock are retained, but in which there has been some metasomatic replacement.

In the same way most of the other terms applied to "processes" are found to be ill-defined. Even metamorphism, which is, in the present connection, used in its limited petrographic sense, is a loose title. Usually it carries with it the idea of rock induration. Its complexity is hinted at by the use of such compounds as "contact" metamorphism and "regional" metamorphism. It actually embraces both metasomatic and paramorphic alteration, and sometimes also mineralization and cementation. Certain diastatic and vulcanic influences also profoundly affect its exact expression.

To one trained in some other than geological science, the most striking feature of the latter is a certain vagueness that seems to pervade the entire field. This is also the main difficulty that every beginner has to overcome. While after a time this trouble ceases to impress itself on the geologist himself it is nevertheless glaringly apparent in his conversation and especially in his writings. The outcome of closer attention to the only natural scheme of classification, the genetic one, is clearer discrimination of facts, greater precision of statement, and vastly better comprehension of the whole subject.

CHARLES R. KEYES.

Studies for Students.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

IV. AVES.

That the birds were derived from the reptiles there is little doubt, the structure of the limbs, head, the thoracic and pelvic girdles and the feet all show a close resemblance to that of the same regions in the reptiles. Especially is this true in the more primitive birds. The general characters that are used to distinguish the class *Aves* are the development of the anterior limbs as flying organs and the accompanying atrophy of the digits of the front foot; the fusion of the bones of the skull to form a solid brain case; the fusion of the bones of the pelvis to form a solid mass of bone; the fusion of more or fewer of the dorsal vertebræ and the development of feathers. To these characters there might be added for all recent birds the absence of teeth. In the most primitive bird that we know there is not one of these characters developed in anything like a complete state, except the presence of feathers. In fact, if it were not for the fortunate accident of the preservation of the fossil in the fine grained beds of the Lithographic slates of Solenhofen, so that a cast of the feathers has been preserved, there would be some difficulty in deciding the true nature of the animal. The bones of the head and the pelvis are not coössified; the digits of the anterior limb are developed with functional claws; the vertebræ are distinct and there are many teeth in each jaw.

The Dinosaurs have been regarded as the direct ancestors of the birds, both *Compsognathus* and *Ornithomimus* of the Theropodous division having been considered as the forms from which they were derived, however there is not sufficient proof to

warrant our acceptance of either of these forms. Haeckel in his work on the phylogeny of the vertebrates thinks that the ancestor of the birds must be sought among the most primitive of the Dinosaurs of the Triassic or even earlier, among the *Rhyncocephalia* and the *Proganosauria*. Smith Woodward in his very recent work on Vertebrate Palæontology is content to say, "The earliest known birds exhibit a distinct approach to the *Reptilia* in several characters, but do not afford any indication as to the particular group from which they evolved. The general opinion is, that they are more closely related to certain *Dinosauria* than to any other forms hitherto discovered."

Following the classification adopted by Smith Woodward and in Parker and Haswell's Zoölogy, the class *Aves* may be divided into two subclasses, *Archæornithes* and *Neornithes;* the same groups were called by Haeckel, *Saururae* and *Ornithurae*. The first subclass is characterized by the features mentioned above. There is but one genus known and this is represented by but three specimens, two nearly perfect skeletons and a single impression of a feather.

Archæopteryx from the Lithographic Beds of the Upper Jurassic of Bavaria. Besides the characters mentioned above the animal was distinguished by the possession of a very long bony tail with a pair of feathers growing from each vertebra. The body of the animal was well covered with feathers and the remiges of the wings were well developed. It was about the size of the ordinary crow.

The *Neornithes* are divided into two groups, the *Ratitæ* and the *Carinatæ;* the flightless and the flying birds. The first group is of rather variable limits, some authors including in it all the birds without wings or with poorly developed wings without a keel upon the sternum, and without considering the origin of the condition, whether it is original, persistent from very early forms, or whether it is the result of degeneration from lack of use. Thus Smith Woodward includes among the *Ratitæ* certain forms that are considered by other authors degenerate *Carinatæ*.

The divisions *Ratitæ* and *Carinatæ* are assigned different values by the various writers on the subject, some considering them as orders and the other groups of the birds suborders, while others regard them as divisions of their class and all the other groups as orders. Probably the latter has the greatest following among zoölogists. It will be possible here to consider only those groups that are of importance in geological history.

Æpyornithes: extinct, gigantic birds represented by fossils from the post-Pleistocene of the island of Madagascar. They resembled the living *Apteryx* of New Zealand. *Æpyornis* is the most typical genus. It was of great size, the long bone of the leg, tibio-tarsus, was about two feet and a half long. In general form the members of this and the succeeding order resembled the modern ostriches.

Immanes.—The "Moas" or *Dinornithidæ*, were gigantic forms that existed as late as historical time, they were hunted by the natives of the island of New Zealand, where they were developed. They are not known from formations earlier than the Pleistocene, with the possible exception of a few fragments from what may be the Pliocene. They closely resemble the living *Apteryx*, and are sometimes grouped with it and the Emus and Cassowaries in an order *Megistanes*.

Dinornis is the best known of the genera; the scapular arch was almost entirely atrophied and the sternum was entirely without a keel; the hind legs were very stout and strong; the largest known species stood a little over ten feet high.

Pachyornis was remarkable for the massive nature of the hind limbs; as a whole the animal was smaller than the *Dinornis*.

Most of the existing Ratite birds are known from the superficial deposits of the countries where they are now found; an extinct Emu is known from the eastern part of Australia; remains of Rheas are found in South America and the Ostriches are represented by remains from the Siwalik Hills of India and from the Island of Samos in the Mediterranean.

Carinatæ.—Next to the *Archæopteryx*, probably the most interesting group of birds that is known are the peculiar toothed

forms from the Niobrara Cretaceous of Kansas. These were described by Marsh and called by him the *Odontornithes*, he distinguished two orders, the *Odontolcæ* and the *Odontormæ* (*Icthyornithes*).

Odontolcæ: large, flightless, swimming and diving birds that resemble the modern diving birds, Loons, etc., in many respects, and the Ratite birds in others. The front limbs are almost entirely atrophied, the humerus being represented by a slender stylet of bone; the skull was elongate and the jaws were furnished with many sharp teeth that were set in a common groove for each jaw.

Hesperornis, the most typical genus, was a large form about three feet high. A similar form *Enalornis* is indicated by remains from the Greensand of Cambridge, in England, but the structure of the anterior limbs is as yet unknown.

Odontormæ (*Icthyornithes*): much smaller birds than the former with well developed wings; the jaws were long, as in the preceding genus and were provided with teeth that were set in individual sockets; the vertebræ were peculiar in that the faces, both anterior and posterior, were deeply concave. The bird was much like the modern Tern in external characters.

Icthyornis is the only well-known genus from the Niobrara Cretaceous of Kansas.

The modern birds have many representatives among the fossil forms of the late Tertiary, among the most interesting of these are:

Gastornis, a large flightless bird from the lower Eocene of the western part of Europe. It was peculiar in that the bones of the skull remained separate instead of forming the usual solid brain case.

Apatornis, *Diaphaptoryx*, and *Aphanapteryx* from New Zealand, the Chatham Islands, and Mauritius respectively were gigantic rails that greatly resembled certain of the living rails.

Phororachos was an enormous raptorial bird whose remains are found in the Tertiary of Patagonia.

The Dodo (*Didus*) and the Solitaire from the islands of

Mauritius and Rodriguez were large ground pigeons that had lost, to a great extent, the use of the wings ; they were found living by the first travelers that visited the islands, but were speedily exterminated.

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V. MAMMALIA.

The earliest known remains of the mammals are from the Triassic rocks of England and America. Between these earliest of the mammals and their direct reptilian ancestors there is but a very little gap, even in the imperfect record afforded by palæontology. Every step in the transition from the reptilian structure to the mammalian can be traced in the fossil forms, except the final disappearance of a separate bone in the skull, the quadrate, which supports the lower jaw, and the coalescence of the many bones of the lower jaw to form the single mandibular bone of the mammals.

Recalling the structure of the Theriodont and the Gomphodont reptiles of the Permian time we have no need to be surprised at the early appearance of the mammals in time. Speaking of the origin of the mammals, Osborne has said: "Two of the types of the Theromorphs of the Permian and Lower Triassic, namely, the *Theriodontia* and *Gomphodontia*, supply many of the characters which we have expected to find in the ancestry of the Mammals. In fact, they embrace the few osteological characters placed in Haeckel's Promammalia, or Huxley's Hypotheria, as well as the more numerous characters which we have

subsequently put into the mammal archetype. The *Theriodontia* resemble in their dentition and structure the minute *Protodonta* described by Osborne from the Triassic, but differ in the compound character of the jaw bones, as well as in their surpassing size. In tooth structure they are also prototypes of the *Triconodonta* or Marsupials of the Jurassic period. On the other hand, the herbivorous *Gomphodontia*, including *Tritylodon*, are prototypes of the great phylum of Multituberculata, which, in turn, upon extremely slender evidence, however, have been associated with the Monotremata."

So close is the resemblance between the reptiles and the mammals at this point that one of the *Gomphodontia*, the Tritylodon mentioned by Osborne, was originally described from the skull as a mammal by Owen. The Mammalia are generally divided into three subclasses, the *Prototheria*, *Metatheria*, and *Eutheria*.

PROTOTHERIA a small group comprising among the living forms only the peculiar Monotremes, the Duckbill (*Ornithorhynchus*), and the Spiny Anteater (*Echidna*) of Australia. The animals are characterized by the possession of a distinctly reptilian type of shoulder girdle, with distinct interclavicle and coracoid bones; by the presence of a single external opening for the excretory and genital organs and by their oviparous method of reproduction. The Duckbill has an edentulous horny covering to the jaws in the adult stage that has given it its name, but in the very young there are two or more broad flat teeth in each jaw that recall very strongly the teeth of the *Gomphodontia*. There are no fossil remains of these forms known earlier than the Pleistocene. The bones of a large species of the Echidna have been found in deposits of that age in Australia.

The number of forms of the fossil mammals is so great that it will be impossible to discuss many individual genera, as was done with the preceding groups, and in all except especially important cases the descriptions must be limited to the families or even larger divisions.

METATHERIA, animals usually called *Marsupalia;* possessed of

a pouch in which the young are borne by the mother for some time after birth; there are a pair of bones in the abdominal wall that are attached to the anterior end of the pubis on each side and support the pouch; the shoulder girdle is of the usual mammalian type.

Multituberculata, or *Allotheria*, as they are sometimes called, is a group of rather doubtful relations; they have been regarded as belonging to both the *Prototheria* and *Metatheria*, but probably belong with the latter; they are known only from fragments of the skulls and from isolated teeth. The time range of the forms is rather limited, extending from the Upper Jurassic to the Upper Cretaceous. There are three families known: the *Bolodontidæ*, *Plagiaulacidæ*, and the *Polymastodontidæ*.[1]

Bolodontidæ: forms in which the premolars are somewhat molariform and the upper ones have four tubercles. The molars of the upper series have two rows of tubercles. There were strong incisor teeth. *Bolodon*, from the Purbeck layers of Dorsetshire; *Allodon*, from the Upper Jurassic of Wyoming; *Chirox*, from the lowest Eocene, Puerco, of New Mexico.

Plagiaulacidæ: known mostly from the teeth of the lower jaw. The incisors large and rodent-like, the premolars different from the molars, compressed laterally, the posterior one much larger than the rest, and having the side corrugated by deep grooves that extend diagonally in an antero-posterior direction, making the tooth a most efficient grinding organ. The molars low and flat, the lower with two and the upper with, probably, three

[1] The student must recognize that after the mammalian type of life was developed there were no changes in that group of a magnitude comparable with those which produced the various groups of the reptiles. Until comparatively recently the changes considered have been those which centered in the development of the teeth and the limbs, and it was by the study of these changes that the morphology and the classification of the various groups has been worked out. It will thus be necessary to speak in some detail of these regions. For information on this subject the student is referred to the chapter on Kinetogenesis, chap. vi, in PROFESSOR COPE'S last book, Primary Factors of Organic Evolution, published by the Open Court Publishing Company of Chicago, 1896. The book has an especially valuable bibliography of the same subject. PROFESSOR OSBORNE has published in the American Naturalist for December 1897, an illustrated article bearing on the same subject entitled "Trituberculy: A review dedicated to the late Professor Cope.

series of tubercles. *Microlestes*, Upper Trias, Rhaetic, of Wurtemberg and England; *Plagiaulax*, Purbeck of England; *Ctenacodon*, Upper Jura of Wyoming; *Ptilodus*, Puerco Eocene, of New Mexico, under this last name Osborne includes as synonyms most of the names given by Marsh to the forms described by the latter author from the Laramie Cretaceous; *Meniscoessus*, from the Laramie Cretaceous of Wyoming, under this name are grouped as synonyms many of the remaining described forms from the same region. *Neoplagiaulax*, from the lowest Eocene of France; *Abderities*, as well as many imperfectly known forms, from the Eocene, Santa Cruz formation, of Patagonia.

Polymastodontidæ: lower jaw with a very large and strong incisor tooth greatly resembling that of the recent rodents, two large molars with two rows of tubercles and a very small premolar. This form is quite near the rest of the group, but is easily distinguished by the absence of the enlarged premolars and the much larger size of the animal.

Polymastodon, from the Puerco Eocene of New Mexico.

The study of these forms has led to the best knowledge we have of the changing conditions at the end of the Mesozoic time; thus from a comparison of the similar types in the preceding and the succeeding ages we are led to the conclusion that as far as the faunal relations go the Eocene is very much nearer to the Upper Cretaceous than is the Jurassic, and this means, possibly, a slighter change in the conditions, climatic and otherwise. Osborne says: "The Laramie mammals are surprisingly near to those of the Puerco, and in some cases almost identical with them; in other cases they are of a somewhat older type, ... the greatest gap to be filled by future discovery is between this Laramie fauna and the Jurassic. For this Laramie fauna is separated from the Puerco about as widely as the Puerco is from the Wasatch, but no more widely; whereas it is separated by a profound gap from the Jurassic fauna."

The *Marsupalia*, *Metatheria* proper, is divided into two groups, the *Polyprotodonta* and the *Diprotodonta*, according to the presence of two or more than two incisor teeth in the jaws.

Polyprotodonta: carnivorous or insectivorous forms of small size with a large number, 4–5, of incisor teeth and many molar and premolar teeth, 8–12 in opposition to 6–7 possessed by recent forms. The premolars are simpler than the molars.

The suborder is divided by Osborne into three groups, *Protodonta*, *Triconodonta*, and *Trituberculata*. The first, the *Protodonta*, is distinguished by having the premolars simple and conical in shape and the molars with a middle part slightly elevated above a posterior and an anterior accessory cone. The molar teeth are single-rooted, but there is a deep groove on each side that indicates the coming division of the root into two parts. The group is represented by two specimens only. These are from the Triassic rocks of North Carolina and consist of the lower jaws only. *Dromotherium* and *Microconodon*.

Triconodonta: forms very similar to the last, but with a smaller number of molar teeth. The middle cone of the molars is better developed and the accessory cones are separated farther from the main one and have a much greater part in the function of mastication. The roots of the teeth are entirely separated. The forms are almost entirely from the Jurassic layers of England, and Wyoming. Typical genera are:

Amphilestes, Oolite from near Oxford, England.

Phascalotherium, Oolite from near Oxford, England.

Tinodon, Upper Jurassic of Wyoming.

Priacodon, Upper Jurassic of Wyoming.

Dicrocynodon, Upper Jurassic of Wyoming.

Trituberculata: small forms with many molar teeth, the crowns of which are supplied with three tubercles arranged in the form of a triangle with apex of the triangle pointing inwards in the upper teeth and outwards in the lower; the importance of these forms is best realized when we remember that this tritubercular arrangement of the tubercles of the teeth is the primitive type from which all the remaining types of mammalian dentition have been derived. The *Amphitheridæ* and the *Amblotheridæ* are the two most primitive families of the suborder.

Amphitherium, from the Oolite of England, near Oxford.

Amblotherium, from the Purbeck of England.

Dryolestes, from the Upper Jurassic of Wyoming.

The *Myrmecobidæ*, *Peramelidæ*, *Dasyuridæ*, and *Didelphyidæ* are all families containing living forms, the last two have members from rocks as old as the earliest Eocene. It is of interest to note that while the family *Didelphyidæ*, the opossum, is at present confined to the North and South American continents it formerly ranged over the whole of Europe and England.

Diprotodonta.—This suborder is distinguished by the presence of only two incisor teeth in the upper jaw and one in the lower. The premolars are like the molars, or may be developed as long cutting organs, as in the *Allotheria*. There are several families, but only two are of interest to us here, as they are the only ones that contain fossil forms. The suborder, living forms as well as extinct, is entirely confined to the Australian region.

Thylacoleo is the single representative of the *Thylacoleonidae*; it was a large form about the size of the lion, with strong incisors and one of the premolars in each jaw greatly elongated in the antero-posterior direction, and compressed from side to side so as to form a long cutting edge; the rest of the dentition is quite weak. The posterior part of the head is very wide, but it narrowed rapidly as it approaches the anterior end.

Diprotodon and *Nototherium* are the representatives of the *Diprotodontidae*. The skull of the first was nearly three feet long, the incisor teeth were developed as gnawing teeth, with enamel on the outer side only and set in deep alveoli. The posterior teeth lacked the cutting edges of *Thylacoleo*, and were adapted to grinding up vegetable material. The whole form had the bulk of the rhinoceros; the structure of the feet is unknown. *Nototherium* was very similar to this form, but was considerably smaller.

EUTHERIA: Animals in which there is no marsupium; the embryo is nourished by the development of a placenta that attaches it to the mother. This includes all the remaining forms of the mammals. Palæontologists recognize ten orders of the

Eutheria: the *Cetacea*, *Sirenia*, *Ungulata*, *Tillodontia* (?) *Rodentia*, *Carnivora*, *Insectivora*, *Chiroptera*, *Edentata and Primates.*

Edentata.—These are the lowest of the Eutheria in the scale of development. The group is characterized by the imperfect development of the dentition; the teeth are few in number, and the enamel is lacking from the surface in the more recent forms. That they are degenerate forms is shown by the fact that the earlier order had perfectly formed teeth; many of the steps in process of degeneration have been traced. Three suborders are recognized: *Nomarthra*, *Xenarthra*, and *Ganodonta.* The first of these is of little importance from a palæontological standpoint; it is composed of forms confined to the tropical parts of Asia and Africa. It is separated from the *Xenarthra* by characters of the vertebræ.

The *Xenarthra* is divided into five suborders, the *Tardigrada*, *Dasypoda*, *Gravigrada*, *Glyptodontia*, and *Ganodonta.* The first two are confined to the recent and the later Tertiary of South and Central America.

Gravigrada.—These forms, now extinct, were of gigantic size; the body was large and clumsy with a powerful tail that, perhaps, aided the animal in assuming the upright position; in the later forms, perhaps more than in the earlier, the animals walked with the side of the foot presented to the ground; the teeth were few and confined to the posterior part of the jaws; they were without any enamel upon the surface. The animals were in fact large ground sloths; they probably obtained their nourishment by uprooting trees and shrubs and feeding upon the leaves and smaller branches.

Megatherium was the largest of the forms, reaching a length of 18 to 20 feet, and a height of about 8 feet. The teeth placed close together at the posterior part of the jaw, exhibit cross ridges from the presence of slightly harder dentine. The animal is known from all parts of South America, and as far north as Georgia, South Carolina, and Texas.

Megalonyx.—This form is the representative of a separate family from the preceding; the most anterior of the molar teeth

stands far in front of the remainder, and has the appearance of a canine. The genus appears to be confined to the latest deposits of the Tertiary in the United States, and is found in the cave deposits of the southern states. The animal reached the size of an ox.

Mylodon, another form is distinguished from the others by the appearance of slight irregularity in the form of the teeth; instead of straight peg-like form, they are triangular, and the teeth of the lower jaws are somewhat figure eight shaped in outline. This genus was fully as large as the *Megatherium* and had even a greater geographical range, species being known from the pampas of the Argentine Republic, and from the caves of Oregon.

A very large number of forms have been described from the deposits of Patagonia and the Argentine Republic, and a smaller number from other parts of the southern continent, many being found on the west coast, to reach which place they must have either crossed the Andes, or emigrated down the west coast from far up in the United States. The geological range seems to have been from the upper Eocene or the Oligocene to the latest Pliocene.

Glyptodonta.—These were animals in which the body was covered by a strong carapace of bone that was made up of many small ossicles of different shapes, joining each other by suture. The armor was confined entirely to the dorsal surface, there being no plastron or ventral plate as in the turtles. The tail was large and covered with the same armor as the back. The skull was very short and high with a lower jaw of great vertical thickness. The teeth were elongated in the anterior-posterior direction, and the sides of the teeth were marked by deep vertical grooves that nearly divided the teeth into three parts. The vertebræ of the dorsal region were all united into a long tube, and the lumbar vertebræ were anchylosed with the sacrum, thus practically destroying any mobility of the spine. The feet were provided with broad, almost hoof-like claws. The animals sometimes reached a very large size. The whole suborder is extinct.

Glyptodon: a very large form that ranged from the southern part of South America as far north as Texas and Florida. The animal was about six feet long, and reached a height of three feet at the most elevated portion of the carapace. The dermal plates are sculptured in the form of a rosette. The tail is covered with a series of bony rings that are attached to the processes of the vertebræ within.

Panocthus: a large form that is confined to southern part of South America; very similar to the *Glyptodon.* The carapace was made up of four and five-sided pieces with a tuberculated surface instead of the rosette arrangement. The anterior part of the tail was protected by 6–7 large bony rings, but the posterior part was enclosed in a solid tube of bone that was slightly flattened; the surface of this tube was covered with small plates that in places gave room to larger ones that seem to have been the bases of some sort of protuberance, horny or bony. The form reached about the size of a rhinoceros.

A large number of these forms have been described from the late Tertiary deposits of Patagonia, and the Argentine Republic. The majority of them come from the Miocene and the Pliocene, though a considerable number are from the earliest, the Santa Cruz Tertiary.

Ganodonta.[1]—This group was founded in 1896 by Wortman, and considered by him as a suborder of the Edentata. The group is made up of a part of the order *Tillodontia*, which was originally considered as the ancestral form of the rodents. Not until the teeth of one of these forms was found in connection with the fore limb was it determined that they were Edentate in character. The fore limbs are similar in every respect to those of the *Tardigrada*, but the teeth are different in that they are not devoid of the enamel covering and in the presence of the anterior teeth, the incisors, and the canines. These forms occur in the earliest Eocene Puerco beds of New Mexico, and are undoubtedly the earliest forms of the Edentates. They are of

[1]Science, December 11, 1896, p. 865., Bull. Am. Mus. Nat. Hist., Vol. IX, p. 59. (Contains a full description of the Ganodonta and its geological relationship.)

extreme interest as indicating the origin of the group which has been for long one of the greatest problems of the palæontologist. Other than the interest attaching to the origin of the group is that of the geological possibility of the forms getting into the southern continent in the early Tertiary time. These forms undoubtedly originated in the United States. As there is no trace of them in the basal Eocene of South America. and they appear in great numbers and highly developed in the Middle Eocene, it seems certain that they must have emigrated from the northern land. There is little possibility that they could have taken the northern route and gained the land of Asia by the northern connection, and then worked into South America by the Antarctic continent; this is further borne out by the fact that there are no known remains of the group from the Old World beyond the incompletely identified specimen of one genus. It seems probable that there must have been a temporary connection between the two continents in the earliest or the Middle Eocene. That the forms found the conditions of life exceptionally favorable in the southern continent is evidenced by the extraordinary development both of species and of individuals.

Cetacea.—This order bears very much the same relation to the land mammals that the Plesiosaurs and the Icthyosaurs bore to the early land reptiles. The limbs have degenerated and become adapted as swimming organs, the bones of the proximal portions becoming shorter and losing their distinctive character, while the phalanges become much more numerous and there may even be added digits. In most of these forms also the hind limb is lost; the teeth become simpler and disappear in some forms; the whole body takes on the fish-like form that seems to be requisite for the aquatic life; the hair disappears and is represented by only a few scattering bristles. These remarks are equally applicable to the succeeding group, the *Sirenia.*

The *Cetacea* are generally divided into three groups, the *Archaeoceti*, the *Odontoceti*, and the *Mysticoceti*. The last two groups, the recent dolphins and the whales are represented in the fossil state by specimens from the Eocene, showing all the

characters of the recent forms. The first group, the *Archaeoceti*, is represented by a form that is known from all parts of the world, *Zeuglodon;* it has an elongate skull like the alligator, but still possesses the dentition of the land animals, in that it is differentiated into premolars and molars; the position of the nostrils and the extent of the nasal bones are also typical of the land forms, but the limbs are those of a water animal. As the form is the earliest known, it is regarded as the nearest to the primitive ancestor of the *Cetacea*. The carnivorous dentition has led to the conclusion that it, and consequently all of the order was derived from a carnivorous mammal. The high degree of development of the order at its earliest appearance, indicates that these animals must have begun their specialization some time in the Cretaceous before we know of any mammals that could have produced them.

The *Sirenia* have a like history to the foregoing group. They are, without doubt, the descendants of land-living forms, but are derived from ungulates, probably from the primitive *Condylarthra*, instead of from carnivorous forms. The earliest remains are from the Eocene rocks, and show that the animal was at that time still in possession of a pair of rudimentary hind limbs. Specimens are known from most of the countries of the earth, and from all deposits from the earliest Eocene up. *Rhytinia*, Steller's Sea-cow, became extinct as late as the middle of the eighteenth century. It was found in great abundance on the shores of Alaska and the neighboring islands by the early explorers, and was slaughtered for food by the whalers.

Ungulata.—This is one of the largest groups of the mammals, including all of the herbivorous forms with the exception of the rodents. They are all land-living forms, with the limbs modified as organs of locomotion and the terminal phalanges armed with broad, flat, horny coverings or hoofs. The dentition is adapted to a vegetable diet or to an omnivorous one, as in the pig. The dentition is diphydont, *i.e.*, there is a milk set that is later replaced by a permanent one.

There are generally recognized eight suborders of this order:

Condylarthra.
Perissodactyla.
Artiodactyla.
Amblypoda.
Proboscidea.
Toxodontia.
Typotheria.
Hyracoidea.

The *Condylarthra* are forms with five functional digits on each foot; plantigrade in the habit of walking, and with small hoofs on each digit. The astragulus has a long neck, and the distal articular face, for the navicular, is rounded. The teeth are multitubercular and complete in number in each jaw. It was in these regions that the changes took place that have made it possible to trace out the lines of development of the ungulates, and, as Cope thought, the lines of the *Carnivora* and the *Primates* as well.

There are several families of the suborder, but it will be as well, probably, to take one of the forms from one of the families and describe it as typical of the whole group.

Phenacodus is the best known of the suborder. By great good fortune the nearly perfect skeletons of two individuals are known. The whole animal was about the size of a mastiff dog. The first and fifth toes on both the fore and the hind feet are shorter than the others, and show already the tendency to a reduction in number that is the dominant line of evolution in the foot structure of the ungulates. Another thing, the bones of the two rows of the carpus and the tarsus are arranged one above the other, instead of being alternate in position, *i. e.*, one of the upper row being opposite the space between two of the lower row. The latter arrangement is readily seen to be by far the strongest, and the development of the ungulates is marked by the gradual acquisition of this alternate arrangement of the bones in place of the serial arrangement of the *Condylarthra*. There was a long tail; the skull was low and flat, with large

orbits that are open behind; the multitubercular teeth indicate that the animal was omnivorous in its diet; the brain was small and smooth, devoid of deep convolutions such as exist in most of the mammalian brains.

Periptychus was a very similar form from the same horizon as Phenacodus.

Pleuraspidotherium and *Orthaspidotherium* are forms from the lowest Eocene, Cernays, of France; they are similar in the essential features to the American *Condylarthra*, and show that the group was widespread in its geographical range, as might be expected from its generalized characters.

Starting from the *Condylarthra*, with its generalized dentition and five-toed feet, there were developed two lines of the *Ungulata*, which include all of the living and extinct forms. In one line the weight of the body is borne on the three middle digits of the feet, or, in the more advanced forms, on the middle one of all the digits. These forms were called by Owen, in 1849, the *Perissodactyla*. They are generally referred to as the "odd-toed" animals, with the idea that there is always an uneven number of toes on the feet, but this is erroneous, as some members of the group have four toes on the feet; the essential thing is that only three of them take any part in supporting the body, the other being a rudiment from the original pentadactyl arrangement. The next group of the *Ungulata* is the *Artiodactyla*, the forms with an even number of toes supporting the body. There are, of course, many points in the structure of the two groups that are correlated with the development of the toes; thus, in the first group there are never any horns developed on the parietal bones, and the horns are never paired, but there are horns developed on the median line on the nasal bones, as in the rhinoceros. There is no living form of the *Perissodactyla* that ruminates; there is a characteristic number of dorsal vertebræ for each group; the astragalus of the two groups has a very different form, and there is always a third trochanter on the femur of the odd-toed forms.

Osborne, in Part I of his memoir on the Extinct Rhinoce-

roses, has given perhaps the best summary of the position of these forms. He says: "The Perissodactyla may be primarily divided by the fundamental pattern of their upper grinding teeth into four superfamilies, as follows:

1. Titanotheroidae: including the single family (1) *Titanotheridæ.*

2. Hippoidea: including the two families (2) *Equidæ* and (3) *Paleotheridæ.*

3. Tapiroidea: including the two families (4) *Tapiridæ* and (5) *Lophiodontidæ.*

4. Rhinocerotoidea: including the three families (6) *Hyracodontidæ*, (7) *Amynodontidæ*, and (8) *Rhinocerotidæ.*

To these should be added:

5. Chalicotheroidea, an aberrant superfamily, with molar teeth related to the Titanothere pattern, and perissodactyl feet provided secondarily with claws.

The eight families, in the order named, may be imagined as the contemporary branches of the four superfamilies, these in turn having branches from a still unknown Perissodactyl stem form — probably a Cretaceous member of the Condylarthra.

These eight families, familiarly known as the Titanotheres, Horses, Paleotheres, Tapirs, Lophiodonts, Hyracodonts, Amynodonts, and Rhinoceroses, when regarded as a series, present upon the one side close resemblances, or perhaps affinities, to the Artiodactyla, and an extreme departure from the Artiodactyla on the other. Thus the Titanothers exhibit many resemblances to the Artiodactyls, while the Rhinoceroses exhibit none at all, and are in many respects the most typical Perissodactyls.

Superfamily Rhinocerotoidea, or Rhinocerotine group. The three distinct families included in this division may be popularly known as the Cursorial or Upland Rhinoceroses, the Aquatic Rhinoceroses, and the True or Lowland Rhinoceroses. They are briefly distinguished as follows:

Hyracodontidæ: cursorial rhinoceroses; *Hyrachyus* and *Hyracodon;* manus functionally tridactyl; upper and lower incisors and canines persistent and uniformly developed.

Amynodontidæ: Aquatic Rhinoceroses; *Amynodon* and *Cadurcotherium;* manus functionally tetradactyl; incisors atrophied; upper and lower canines greatly enlarged.

Rhinocerotidae: True Rhinoceroses; *Aceratherium* and *Rhinoceros;* manus functionally tridactyl; upper canines atrophied; median upper incisors and lower canines opposed and irregularly developed.

Our knowledge of the three divisions of this superfamily extends back only to the Middle Eocene of America and Europe, namely, to the Bridger and the somewhat older Egerkingen Beds of Switzerland. No Rhinoceroses of any kind have as yet been found contemporary with the primitive Horses and Tapirs of the Wasatch of America or the Suessonian of France, but they will undoubtedly be discovered in these or older rocks either in America or Europe, with characteristics as sharply defined as those of the other perissodactyl families.

Certainly before the Middle Eocene of North America, the Rhinocerotoidea had here or in some unknown region specialized and diverged into the three above-mentioned families, which some authors place in the single family Rhinocerotidæ. While it is quite possible that in the Wasatch or Suessonian period this group consisted of a single family, in the Bridger we certainly find two distinct families, the Hyracodontidæ and Amynodontidæ, and in the White River these coexist with the Aceratheriinæ, or ancestral true Rhinoceroses. The members of each family were evidently as widely different in their external form as in their dental and skeletal structure. . . . .

There is no doubt, therefore, that as a matter of taxonomic clearness as well as of phylogenetic fact it is best to consider these three families as entirely separate and undergoing a parallel development, probably in Europe as well as in America.

Specialization in habits.—The wide separation of these three families will be fully apparent after we have examined their chief primitive, parallel, and divergent features. Parallelism is mainly confined to the evolution of the molar teeth, for in every feature of the incisor teeth, the skull, the vertebræ, and the limbs, these

families specialized and diverged rapidly. The rhinocerotine differentiation in the broad sense of the term, imitated that of the Perissodactyla as a whole in its general functional radiation. They ran either into upland cursorial types, which competed with the Horses and the Ruminants, or into the lowland marsh or river dwellers, which competed with the Tapirs and the Titanotheres.

Among the former were the smaller, more agile, light-chested types of Hyracodonts, simultating the Miocene Horses in skeletal structure and in the development of true hoofs. Among the latter were the short, heavy types of Amynodonts, with broad, spreading, padded feet; they probably acquired, like the Tapirs, a long, prehensile upper lip, or, possibly, a true proboscis was developed, in correlation with the rather abbreviated nasals. The elevated and prominent position of the orbit would bring the eye near the surface in swimming. This feature, with the long, curved tusks, undoubtedly used in uprooting, suggests the resemblance between the habits of these animals and those of the Hippopotami. The early Aceratheres were light-limbed rather swift-footed animals, intermediate in proportions between the Hyracodonts and the Amynodonts, but far less graceful and rapid than the former, yet the destiny of this family was also to finally produce both the very slow, heavy-bodied forms, such as *Aceratherium* (*Aphelops*) *fossiger*, of the Loup Fork and the stilted, long-limbed *Aceratherium malacorhinum* of the same period.

Neither the Hyracodonts nor the Amynodonts developed horns, and all the early true Rhinoceroses had weak, hornless, nasals so that they probably appeared externally more like enlarged modern Tapirs than the well-armed animals we are now familiar with.

They did not interfere with each other because each enjoyed a different local habitat, while occupying the general geographical regions. The Hyracodonts dwelt in the drier grassy plains. The Amynodonts frequented the river and lake borders. Up to the time of the extinction of these two related families, the true

Rhinoceroses maintained a somewhat uniform structure, both in Europe and America, differing, so far as we know, in size rather than in proportions. Their dentition and their feeding habits were probably similar to those of the *R. bicornis* of Africa and the *R. sondaicus* and *R. sumatrensis* of Asia, namely, upon leaves, shrubs, and softer herbage. After the extinction of the rival families, however, there was naturally a tendency on the part of the true Rhinoceroses to enter the peculiar local habitats previously occupied by the Hyracodonts and the Amynodonts, and they accordingly diverged into upland and lowland, short and long-limbed, brachydont and hypsodont types.

Geological and geographical distribution.—(1) The Hyracodontidæ, including *Hyrachyus*, *Triplopus*, and *Hyracodon*, are very abundant, displaying a great range of size in the Middle Eocene and Oligocene of North America, and are possibly represented in the Eocene of Europe by species which have been mistakenly referred by Rutimeyer and others to *Lophiodon*. (2) The Amynodontidæ are known from the Upper Eocene or Washakie and Uinta Beds of North America, and are also possibly represented by species referred to *Lophiodon* in the Eocene of Europe, although it is difficult to determine this from the teeth alone; the latest American type is *Metamynodon* of the Oligocene, but *Cadurcotherium* represents a later and probably final stage of development in the Oligocene and Lower Miocene of France. (3) The Rhinocerotidæ are first doubtfully known in the Upper Eocene of Europe, then suddenly appear in abundance in the Lower Oligocene. They are grouped in four subfamilies. (1) Aceratheriinæ of Europe and America. These hornless types ranged through all the Miocene of North America, and then apparently became extinct upon this continent, but in Europe they extended into the Pliocene, and in Asia into the Middle Pliocene. (2) The Diceratheriinæ, or pair-horned types, have been found only in the Lower and Middle Miocene of North America and Europe. (3) The earliest Rhinocerotinæ, or Rhinoceroses possessing median horns, branched off from the Aceratheres in the Middle Miocene of Europe; they divided into three sub-

series which are scattered widely over Europe, Asia, and Africa, and displayed a remarkable specialization. (4). The most aberrant family is the Elasmotheriinæ, thus far found only in the Pleistocene of Siberia."

DISTRIBUTION TABLE, AMERICAN HORIZONS.

	Lower Eocene *Wasatch*	Middle Eocene *Bridger*	Upper Eocene *Uinta*	Oligocene *White River*	Lower Miocene *John Day*	Upper Miocene *Loup Fork*
I. HYRACODONTIDÆ.						
Hyrachyinæ						
Hyrachyus	......	×				
Colonoceors	......	×				
Triplopodinæ.						
Triplopus	......	.....	×			
Hyracodontinæ						
Hyracodon	......	......	......	×		
II. AMYNODONTIDÆ						
Amynodon	......	×				
Metamynodon	......	......	......	×		
Cadurcotherium [1]						
III. RHINOCEROTIDÆ						
Aceratheriinæ	......	......	......	×	×	×
Diceratheriinæ	......	......	......	......	×	
Rhinocerotinæ.						

The superfamily TITANOTHEROIDÆ, with the single family *Titanotheridæ* is generally divided into two subfamilies, the *Paleosyopinæ* and the *Titanotherinæ*. The group seems to have developed in the later Eocene time, and to have reached its greatest development in the Miocene near the middle of which time it disappeared. Starting with forms about the size of the Tapirs of modern time the animals gradually increased in size until at the time of their extinction they had reached elephantine proportions. In general appearance they must have been similar to the Tapirs, with a broad, heavy body, stout limbs and a long upper lip. The brain cavity was small, and the brain was probably devoid of deep convolutions. The group reached by far its greatest development in North America, but a few forms have been discovered in the Upper Eocene and the Lower Mio-

[1] Phosphorites of Quercy.

cene beds of Europe. The two subfamilies differed chiefly in the larger size and the more complex dentition and foot structure of the *Titanotherinæ*.

Paleosyops is the most characteristic member of the first subfamily. It is found in the Lower and Middle Eocene of North America (Wind River and Bridger). The dentition was complete, that is, the incisors and premolars were all present; the premolars were simpler than the molars; the skull was without horns and without the concave outline of the upper surface that is so apparent among the Titanotheres. One species was about six feet long and three feet high.

Diplacodon from the Upper Eocene of the United States, Uinta, is of great interest in that it is in many characters related to the Rhinoceroses, and at the same time stands as an almost perfect connecting link between *Paleosyops* of the Lower Eocene and the Titanothers of the Miocene.

Titanotherium was a large form confined to the Lower Miocene and reaching its greatest development in the United States; a few specimens have been found in Europe. Despite the rather short time in which the animal lived upon the earth it developed an astonishing degree of variability, with the result that it has probably received as many different names as any form known. Thirteen genera and thirty-one species have been described from what Osborne, after a careful study of the cranial characters, regards as "one or possibly two genera, and about fourteen definable species." The Titanotheres are characterized by the development of a pair of horns on the anterior portion of the snout; the gradual loss or the tendency to the loss of the incisor teeth; the complex dentition, in which the premolars are as complex as the molars and the increased size. The largest species reached a length of between twelve and fifteen feet and a height of about seven feet. Remains are known from a large number of regions in the United States and Canada, showing that the animal roved over a wide territory.

E. C. CASE.

REFERENCES FOR THE MAMMALS HERE DISCUSSED.

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OSBORNE, H. F., The Reports of the American Museum of Natural History contains many papers by Osborne, Wortman, Earle, and others upon the collections of mammals from the Tertiaries of the United States. These are fully illustrated, and are intended as guide books, to a certain extent, to the specimens in the museum. Among these are Wortman's paper upon "Ganodonta."

COPE, E. D., Tertiary Vertebrata, Vol. III. United States Geological Survey of the Territories, 1884.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

TODD[2] maps and gives a general description of the geology of South Dakota. Archean[3] rocks are present in the Black Hills, near Sioux Falls, and near Bigstone Lake in the eastern part of the state.

In the Black Hills the Archean rocks are slates and schists, intruded by granite. The metamorphic effects in the slates and schists become more pronounced as the contact with the granite is approached. Following Van Hise, it is believed that their metamorphism was largely brought about by the intrusion of the granite. The thickness of the slates and schists is from 10,000 to 100,000 feet. In age they are believed to correspond to the Lower Huronian of the Lake Superior region. The granites, while younger than the slates and schists, are still pre Cambrian.

The Sioux quartzite is similar to the quartzite of Baraboo and the Chippewa valley, of Wisconsin, and, following Irving and Van Hise, it is believed to be of Upper Huronian age.

Near Bigstone Lake are exposures of granites, probably of Laurentian age.

All the Archean rocks are overlain unconformably by Cambrian rocks which in general dip away from the Archean exposures.

Keyes[4] gives the result of an examination of the Sioux quartzite. Impressions were seen at several points in the bedding planes of the quartzite which so much resembled those of lamellibranchs of the Cardium and Cytherea types, that, notwithstanding strong pre-conceived notions of the ancient age of the Sioux rocks, faith in their old age was very much shaken. It is concluded that the Sioux formation should be considered as pre-Cambrian until indisputable evidence to

[1] Continued from p. 753, Vol. VI, JOUR. GEOL.

[2] A preliminary report on the geology of South Dakota, by J. E. TODD. South Dakota Geol. Survey, Bull. No. 1, 1895, pp. 172. With map.

[3] Archean is used to designate the pre-Cambrian.

[4] Opinions concerning the age of the Sioux quartzite, by C. R. KEYES. Proc. Iowa Acad. Sci. for 1894, Vol. II, 1895, pp. 218–222.

the contrary is produced, but that there now exist certain doubts concerning the accuracy of this view.

Keyes,[1] in an account of the characteristics of the Ozark Mountains, briefly describes the Archean and Algonkian rocks of the region. Archean rocks occur at the east and west ends of the Ozark uplift. The best known of the areas is the eastern one, the Iron Mountain district of southeastern Missouri. Here the largest areas occur in the vicinity of the peak from which the district takes its name, and other smaller areas are scattered over a considerable range of adjacent territory. The Archean rocks in the Iron Mountain district are granites and porphyries, the latter predominating, both of which are broken through in numerous places by basic intrusives.

At the western end of the Ozark uplift, in Indian Territory, are Archean rocks, principally granites, of which there are many varieties, cut, as in southeastern Missouri, by dikes of basic material.

Immediately overlying the Archean in a number of places are beds of conglomerates and slates provisionally referred to the Algonkian. These appear to best advantage on Pilot Knob.

Haworth[2] describes and maps the pre-Cambrian geology of the area of the Iron Mountain sheet in southeastern Missouri, which covers portions of Iron, St. Francois, and Madison counties. The pre-Cambrian rocks are crystalline, massive, Archean rocks, and crystalline, stratified, Algonkian rocks.

The Archean rocks in general form the uplands. They may be divided into two general classes, basic eruptives and acid eruptives, including granites and porphyries.

The basic eruptives, of remarkably uniform character, occur principally in the southeastern part of the area, usually in dikes cutting through the granites and porphyries, but in a few cases in the form of bosses almost circular in outline. The general trend of the dikes is northeast-southwest.

The granites occur mainly in two large areas, though they are found occasionally in small patches within the porphyries. The two

[1] Characteristics of the Ozark Mountains, by C. R. Keyes. Rept. Missouri Geol. Survey, Vol. VIII, for 1894, pp. 317–352. 1895.

[2] Report on the Iron Mountain sheet — the Archean rocks, by Erasmus Haworth. Rept. Missouri Geol. Survey, Vol. IX, 1896, pp. 15–27. With Sheet No. 3.

areas are the Graniteville and Stout's Creek or St. Francois areas. The porphyries occur in numerous large, uniformly distributed areas, making up nearly half the area of the entire sheet. They include what have been called by other writers quartz-porphyry, feldspar-porphyry, felsite, felsophyre, and orthophyre.

Numerous observations show gradations between the granites and porphyries, and it is concluded that the granite and porphyries were formed from the same or similar magmas, and that their difference in texture is due to crystallization under different conditions.

Algonkian rocks are found near the center of the area, capping the Archean rocks of Pilot Knob. They comprise conglomerates and slates, chiefly the former, and include the iron ore deposits of the locality. The pebbles of the conglomerate are mostly derived from the porphyry. The matrix is a fine felsitic mass mixed intimately with varying amounts of hematite. In places the ore forms almost the entire body of the rocks.

Paleozoic rocks unconformably overlie the crystallines, and dip away from the Archean hills.

Keyes and Haworth[1] describe and map the geology of the Mine Le Mot sheet, which includes portions of Ste. Genevieve, Madison, and St. Francois counties, Missouri. Archean rocks, described by Haworth, occupy about half of the area of the sheet, forming the nucleus about which later formations are exposed in concentric belts. They are granites and porphyries, cut by dikes of diabase. The acid rocks greatly predominate, the granite making up fully nine tenths of the eruptives of the area. The porphyry appears to be the surface facies of the granite, and seems to graduate downward into the latter. This is shown where erosion has been great, and has left high granite hills which are often capped by porphyry.

Cambrian rocks directly overlie the Archean rocks, with unconformable relations.

Keyes,[2] considers the granites and porphyries in the eastern part of the Ozarks. Agreeing with Haworth, he finds the granites

[1] Report on the Mine Le Mot sheet -- General geology, by C. R. KEYES; Archean geology, by C. R. KEYES and E. HAWORTH. Rept. Missouri Geol. Survey, Vol. IX, 1896, pp. 14–44. With Sheet No. 4.

[2] Geographic relations of the granites and porphyries in the eastern part of the Ozarks, by C. R. KEYES. Bull. Geol. Soc. Am., Vol. VII, 1896, pp. 363–376. Pl. 17.

and porphyries to be different facies of the same magma. Further agreeing with Haworth, he finds that the granite occupies the lower ground, the porphyries the higher ground, and that, where there are gradations between the two, the granites are at the base of the hills while the porphyries are at the top, with transition zones between. The granites occupy a comparatively small area in the northeastern part of the district. This is an area of low elevation and near the Mississippi River, and distribution is explained as due to differential erosion. The physiography of the district is discussed, and the conclusion is reached that the crystalline rocks have undergone very considerable erosion since Cambrian time. Agreeing with Van Hise, it is held as probable that the granites and porphyries are of Algonkian age. A deep boring near Kansas City at a depth of 2500 feet penetrated black foliated mica-schist, which has the characteristics of the Archean rocks.

Keyes,[1] in connection with a description of the clay deposits of Missouri by Wheeler, briefly discusses their geological occurrence. Most of the ore-bearing conglomerates of Pilot Knob and vicinity, heretofore called Algonkian, are believed to be Cambrian. The granites and quartz-porphyries of the region are not really of Archean age, as generally considered, but are probably Algonkian. In chemical, mineralogical, and structural characters, and in absence of dynamic effects, they differ from the gneissic and schistose rocks which have been reached in deep drill holes, and, therefore, they are believed to be younger than such gneissic and schistose rocks (which, it may be inferred, are believed to represent the Archean).

The geological conditions of the crystalline rocks are unfavorable to clay deposits.

Comment.— No reasons are given for the belief that the ore-bearing conglomerates of Pilot Knob are Cambrian rather than Algonkian. Until adequate reasons are presented, the conclusion of Haworth, Van Hise, and other workers in the field, that the rocks are Algonkian, must be presumed to be correct.

McConnell[2] reports on an exploration of the Finlay and Omenica

[1] Clay deposits, by H. A. Wheeler — Chapter on the geological occurrence of clays, by C. R. Keyes. Missouri Geol. Survey, Vol. XI, 1896, pp. 36–37.

[2] Report on an exploration of the Finlay and Omenica rivers, by R. G. McConnell. Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part C, 1896, pp. 40.

rivers in the Rocky Mountains of western Canada. The Archean[1] rocks of the district consist of a series of well foliated mica-gneisses, mica-schists, hornblende- and actinolite-schists, quartzose schists, and crystalline limestones. The rocks of the series are usually evenly bedded, and conform in dip to the overlying formations. To the series the local term Shuswap is applied.

Shuswap rocks are found on both sides of the Finlay River, from its mouth up to its junction with the Ingenica. North of this point the formation divides. The eastern limb follows the eastern slope of the Finlay valley northwestward to the Quadacha and for some distance beyond. It has a width of four miles at Paul's Branch, where it forms the most westerly range of the Rocky Mountains. This width decreases towards the north and increases to the south. The western limb bends away from the Finlay above the Ingenica, but crosses it again at the great bend which the Finlay describes after leaving the Rocky Mountains, and continues on to the north. The width of this band was not ascertained, as its western boundary was not reached.

Another area of Shuswap rocks, separated from the first by a band of limestones, occurs on the Omenica River above the Oslinca. The band has a width of ten miles.

The Shuswap series is overlain by Lower Paleozoic strata.

Peale[2] maps and describes the geology of the Three Forks quadrangle of Montana. Archean gneisses and Algonkian sediments occupy large areas. The Archean gneisses occur principally in the foothills of the Bridger range, the mountain masses at the northern and southern ends of the Madison range, west of the Madison valley and north of Virginia City, the southern part of the Jefferson range, the foothills of the Gallatin range, south of the Gallatin valley, and beneath the Bozeman Lake beds at the southern end of the plateau, between the Gallatin and Madison valleys. The rocks referred to the Archean may possibly include some that eventually may be referred to the Algonkian. The contacts of the Archean with the overlying sedimentaries are, in all cases, unconformable.

The Algonkian series comprises two divisions, the Cherry Creek beds, and the Belt formation.

[1] In conformity with the usage of Canadian geologists, Archean is above used in the sense of pre-Cambrian.

[2] Geol. Atlas of the United States, Three Forks Folio, No. 24, by A. C. PEALE. Washington, 1896.

The Cherry Creek beds occupy an area of thirty to forty square miles in the foothills immediately west of the Madison River and a few miles north of the southern boundary of the quadrangle, and also a small area on the east side of the Madison valley, at the western edge of the Madison range. The rocks are marbles and interlaminated mica-schists, quartzites, and gneisses. Between Cherry Creek and Wigwam Creek, on the west side of the Madison valley, Cambrian strata rest unconformably upon the upturned edges of the Cherry Creek beds. Before the deposition of the Belt formation, the Cherry Creek beds suffered extensive deformation.

The Belt formation occurs in the northern portion of the district —in the foothills of the northern portion of the Bridger range, in the hills north of the Gallatin and East Gallatin rivers, and in the rugged hills of the Jefferson canyon. In the lower portion of the formation are coarse sandstones and conglomerates, in the central part appear argillites and siliceous limestones, and in the upper part sand stones predominate. The Belt formation is overlain by the Flathead (Cambrian) quartzite. It is possible that further investigation may result in the reference of this formation to the lower part of the Cambrian. At present, however, it is referred provisionally to the Algonkian.

The Flathead and Gallatin formations (Cambrian) rest with marked unconformity upon the Archean for three fourths of the district; for the remainder of the district they rest upon the Algonkian, and the unconformity, if it exists, is very slight.

Weed and Pirsson map[1] and describe the geology of the Castle Mountain mining district of Montana. The Belt group of rocks, assigned to the Algonkian, occupies large areas in the district. The series presents no definite lithological horizons, but there is a general sequence, from the base upward, as follows:

Alternating shales and sandy beds.

Dark gray, laminated, thinly-bedded limestone.

Pearl-gray sericitic shales.

Sandy shales, with thin beds of ripple-marked sandstone.

Red shales and slates.

The series has thus far yielded no fossils. It attains a thickness of 8000 feet. Basic and acid intrusive rocks penetrate the Belt formation very freely.

[1] Geology of the Castle Mountain mining district, Montana, by W. H. Weed and L. V. Pirsson. Bull. U. S. Geol. Survey, No. 139, 1896, pp. 165. With geol. map.

At many localities the Belt series is seen to be in conformable relations to overlying fossiliferous rocks of Cambrian age, the Flathead and Gallatin formations, and, while assigned to the Algonkian, the series is spoken of as forming the lower part of the Paleozoic of the area.

Comment.— It is unfortunate that rocks assigned to the Algonkian should be spoken of as forming the lower part of the Paleozoic, even though the Belt series may be a downward conformable extension of the Paleozoic. If properly Algonkian, *i. e.*, sedimentaries and equivalent igneous rocks below the Olenellus horizon, whether conformable or not, if referred to any era, they should be referred to the Proterozoic.

Weed and Pirsson[1] briefly describe the geology of the Little Rocky Mountains of central Montana. The core of the mountains is formed of crystalline schists, of which the type most usually seen is a black glistening amphibole-schist, or amphibolite. In the saddle west of Shellrock Mountain, the series consists of amphibole-schists and mica-schists, pink gneiss, and white quartzites, the various rocks occurring in rapidly alternating beds but a few feet thick.

The crystalline schists are overlain by Cambrian sedimentaries. Intruded between the schists and sedimentaries is a great laccolithic body of granite-porphyry.

The presence of the quartzite is taken as indicating the Algonkian age of the crystalline series. However, similar schists occurring in Montana have been generally classed as Archean, and these rocks are metamorphosed and quite unlike the slightly altered Belt Mountain Algonkian series. The crystallines are, therefore, not definitely assigned to either the Archean or Algonkian.

Hague, Weed, and Iddings[2] map and describe the geology of the Yellowstone National Park, Wyoming. Archean rocks are found near the borders of the district in the mountain ranges which encircle the Park plateau. They comprise granites, gneisses, and schists. The granites and gneisses are for the most part coarsely crystalline, and the entire series shows the effect of metamorphism by pressure.

Algonkian rocks are recognized only in the southern end of the

[1] The geology of the Little Rocky Mountains, by W. H. WEED and L. V. PIRSSON. JOUR. GEOL., Vol. IV, 1896, pp. 399–428.

[2] Geol. Atlas of the United States, Yellowstone National Park Folio, No. 30, by ARNOLD HAGUE, W. H. WEED, and J. P. IDDINGS. Washington, 1896.

Park, and are best exposed on the southern slope of Mount Sheridan, from which the formation has been called the Sheridan quartzite. The Sheridan quartzite formation comprises sandstones and slates, which contain no fossils. Unconformably overlying the Sheridan quartzite is the Ellis (Juratrias) limestone. The assignment of the formation to the Algonkian is based largely on the fact that similar rocks are unknown in the Paleozoic series, and on the fact that no sedimentary rocks older than these quartzites are exposed in this district.

Hague,[1] in a discussion of the age of the igneous rocks of the Yellowstone National Park, mentions the occurrence of rocks of Archean age in the surrounding mountain ranges. The Tetons, bordering the park to the south, consist mainly of an Archean mass, which towers high above all later rock formations. In the Absaroka range, stretching along the entire east side of the park, and formed mainly of igneous rocks, granite and schists are exposed at the northern end. The Snowy range, which shuts in the park to the north, is largely made up of Archean schists, gneisses, and granites, associated with the more recent outbursts of lava. In the Gallatin range, on the west, a body of crumpled gneisses and schists forms the nucleus of the mass. The Archean masses formed either a part of a broad continental mass, or a group of closely related islands. Resting unconformably upon the Archean are great thicknesses of Paleozoic and Mesozoic rocks.

Eldridge[2] gives an account of a geological reconnaissance across Idaho, on a northeast line through Boisé and Salmon City. Rocks are found which are provisionally referred to the Archean and Algonkian. To the Archean are referred granite and gneiss, which have their greatest development in the mountains of the western part of the state, but which are also widely exposed elsewhere. In places in the granite and gneiss are included bands of calcareo-micaceous or quartzitic slates, and in these cases the reference of the rocks to the Archean, instead of the Algonkian, is questionable. To the Algonkian is provisionally assigned the great series of micaceous, quartzitic, and chloritic schists of eastern Idaho. The reference is based merely upon

[1] The age of the igneous rocks of the Yellowstone National Park, by ARNOLD HAGUE. Am. Jour. Sci., 4th ser., Vol. I, pp. 445–457, 1896.

[2] A geological reconnaissance across Idaho, by GEORGE H. ELDRIDGE. Sixteenth Ann. Rept. U. S. Geol. Surv., Part II, 1895, pp. 217–276.

lithological character, and the resemblance to other beds in the Cordilleras which have already been so assigned. The Algonkian series in areas of strong development has a probable thickness of 3000 to 4000 feet. It is believed to be unconformable with the underlying granite.

Cross[1] describes the geology of the Cripple Creek district of Colorado. The account of the general geology is substantially the same as that previously given by Cross for the Pike's Peak quadrangle,[2] of which the Cripple Creek district is a part. Granites and gneisses occupy a large area in the district. Included in these granites and gneisses are large and small fragments of quartzite, quartz-fibrolite-schist, quartz-mica-schist, and other similar rocks. It is believed that the quartzite fragments belong to a great series of pre-Cambrian (Algonkian) sediments. Hence the granites including such fragments are not Archean; but they are older than the only Cambrian rocks as yet identified in Colorado, and they are therefore mapped as Algonkian. The schists are probably also sedimentary, but it is quite possible that some, if not all, have been produced from Archean gneisses forming the foundation upon which the Algonkian sediments were laid down.

Emmons, Cross, and Eldridge[3] describe and map the geology of the Denver basin in Colorado. Pre-Cambrian rocks form the mass of the Colorado or Front Range along the western border of the Denver Basin, later formations resting against the flanks of the mountains. In the lower canyons of South Boulder and Coal creeks, are beds of highly altered quartzite and conglomerate, associated with schists, aggregating a thickness of 1000 feet, which occupy a position between Triassic sandstones and the gneisses of the interior of the range. These are undoubtedly sedimentary and are probably of Algonkian age. In passing from these sedimentaries westward toward the center of the range there appear successively gneisses, granite-gneisses, and massive granite. As the areas occupied by the granites and sedimentaries have not been definitely delimited, and as the sedimentaries

[1] General geology of the Cripple Creek district, Col., by WHITMAN CROSS. Sixteenth Ann. Rept. U. S. Geol. Surv., Part II, 1895, pp. 13–109.

[2] Reviewed in this JOURNAL, Vol. IV, 1896, p. 371.

[3] Geology of the Denver Basin in Colorado, by S. F. EMMONS, WHITMAN CROSS, and G. H. ELDRIDGE. Mon. U. S. Geol. Surv., No. XXVII, 1896, pp. 556. With maps.

occupy but a small proportion of the pre-Cambrian area, the sedimentaries are not mapped as Algonkian, but, with the granites, are mapped as pre-Cambrian.

Osann[1] gives the geology and petrography of the Apache (Davis) mountains of western Texas. The oldest rocks found therein are the crystalline schists, which composed the greater part of Carrizo and Van Horn mountains. Here is found a great set of coarsely crystalline gneiss, mica-schist, and associated schistose rocks. These have in general a parallel northwest-southeast strike, which agrees with the axis of the range. Following Professor von Streeruwitz, these are placed with the fundamental rocks.

Sapper[2] describes the geology of Chiapas, Tabasco, and the Peninsula of Yucatan, and mentions the occurrence of Azoic rocks in the Sierra Madre Mountains. These rocks include gneiss, mica-slates, and phyllites. A band in the first northern range of the Sierra, near the plantations of Piedad and San Vincente, trends N. 7° W., and dips 5° to the N.E. Among the bowlders washed down by the Aguacate River may be seen gneiss, mica-slates, and phyllites, which indicate the presence of the crystalline formations also in the interior of the Sierra Madre.

Comment.— The term Azoic is used in a very indefinite way. It apparently is applied to all ancient crystallines, both sedimentary and igneous, and is not necessarily confined to the pre-Cambrian. However, the term is placed as a subheading under sedimentary formations, indicating, possibly, that ancient sedimentaries only are included.

Ells[3] reports on the geology of a portion of the Province of Quebec comprised in the southwest sheet of the eastern townships map (Montreal sheet), and describes pre-Cambrian rocks occurring to the east of the St. Lawrence River. These occur along the axis of the Sutton

[1] Beiträge zur Geologie und Petrographie der Apache (Davis) Mts., West-Texas, by A. OSANN. Min. und Pet. Mitt., Bd. XV, Heft 5, 6, 1896, pp. 394–456, mit Tafeln XI–XII, Fig. im Texte.

[2] Geology of Chiapas, Tabasco, and the Peninsula of Yucatan, by C. SAPPER. JOUR. GEOL., Vol. IV, pp. 938–947, 1896.

[3] Report on a portion of the Province of Quebec, comprised in the southwest sheet of the "Eastern Townships" map (Montreal sheet), by R. W. ELLS. Ann. Rept. Geol. Surv. of Canada, for 1894, Vol. VII, Part J, 1896, pp. 1–92.

Mountain range, and in the anticline east of Memphremagog Lake near Fitch Bay.

The crystalline schists of the Sutton Mountain range may be divided into two principal portions, viz., the gneissic, micaceous, quartzose, and talcose schists of the central portion or that in which the axis of the anticline is situated, and a series of green, chloritic, schistose rocks, with the characters of altered dioritic rocks, constituting an easily separable portion, flanking the central area of schists to the west, and extending from the Vermont boundary to the St. Francis in the vicinity of Richmond. This second or chloritic division is recognized also at various points on the eastern slope of the range, but it does not there present so marked a development. The age of the green schistose, dioritic portion is doubtful, but it appears to coincide to some extent with the Volcanic Group of Selwyn,[1] which he supposed to be probably Lower Cambrian or Huronian.

East of Memphremagog Lake, near Fitch Bay, the pre-Cambrian rocks are schistose, altered, dioritic rocks, occasionally with micaceous bands, and often containing clear grains of quartz. These rocks are apparently allied to the green chloritic schists of the west slope of the Sutton Mountain range, and are placed on the map as doubtfully Huronian.

Cutting the pre-Cambrian rocks, and possibly also later sediments, are a considerable variety of rocks, such as granites, syenites, diorites, diabases, serpentines, traps, etc., evidently of different ages. It is probable that the age of the granites is not far from the close of the Silurian period.

Adams[2] describes and maps the Laurentian area north of the St. Lawrence River, in the northwest corner of the southwest sheet of the "Eastern Township" map (Montreal sheet). This Laurentian area is a portion of the southern margin of the great northern Canadian area of Laurentian rocks. The area is about equally divided between the rocks of the Laurentian system and intrusions of anorthosite which break through them. The Laurentian[3] consists of red and gray ortho-

[1] Stratigraphy of the Quebec Group and the older crystalline rocks of Canada, by A. R. C. Selwyn. Rept. Geol. Surv. of Can., for 1877–8, Part A, p. 3.

[2] Laurentian area in the northwest corner of the Montreal sheet, by F. D. Adams. Supplementary chapter to Ell's report on a portion of the Province of Quebec. Ann. Rept. Geol. Surv. of Canada for 1894, Vol. VII, Part J, 1896, pp. 93–112.

[3] The term Laurentian is thus used as it was by Logan.

clase gneisses, presenting great variations both in structure and composition, with which are associated crystalline limestones, quartzites, and amphibolites. In certain parts of the area two divisions can be recognized in the Laurentian: an upper series, characterized by the presence of crystalline limestones, quartzites, and gneisses of sedimentary origin with a banded structure, called the Grenville series; and a lower series of gneisses in which no limestone, etc., occur, and which possess a foliated rather than a banded structure, known as the Fundamental Gneiss. Grenville rocks are recognized south of Rawdon and in the westerly portion of the St. Sauveur district. The Fundamental Gneiss apparently occupies much of the St. Jerome district. However, it has been found impossible to separate the two series and delimit them on the map.

The composition of most, if not all, of the gneisses belonging to the Fundamental Gneiss can be paralleled among the igneous rocks, and it is concluded that many of these gneisses, at least, were of igneous, probably of intrusive, origin. In the Grenville also some of the gneisses are of igneous origin. However, many are believed to be of sedimentary origin, for the following reasons: (1) they are associated with numerous and heavy beds of limestones and quartzite; (2) they have a prevailing banded character, accompanied by a very extensive recrystallization; (3) graphite is of frequent occurrence in them; (4) chemical analyses show that they have the composition, not of igneous rocks, but of sedimentary sands and muds.

The quartzite is sometimes pure, but frequently holds garnet, sillimanite, or other minerals. The limestones are coarsely crystalline marbles, sometimes pure, but at other times including grains of quartz, pyroxene, phlogopite, graphite, and other minerals.

The anorthosite belongs to the gabbros, but is characterized by the great preponderance of plagioclase feldspar, which is often so abundant as to make up the entire rock. At its contact with the gneisses are many contact phases. The anorthosite has been squeezed and foliated, together with the gneisses which it cuts, and it is concluded that its intrusion antedated at least the termination of the great earth movements which affected the Laurentian in pre-Potsdam times. In proportion as the anorthosites exhibit granulation they become light colored, some of the most metamorphosed ones resembling marble in appearance, although chemically they do not differ from the less modified anorthosites.

On the upturned edges of the Archean rocks, both gneiss and anorthosite, the Potsdam sandstone and other Cambro-Silurian rocks repose in flat and undisturbed beds.

Ells and Barlow[1] describe the physical features and geology of the proposed Ottawa Canal between the St. Lawrence River and Lake Huron. The proposed canal for several hundred miles traverses for the most part Archean rocks nearly at right angles to the strike of their schistosity or banding. The work of Logan, Murray, Lawson, and Adams, and others of the important workers on the Canadian crystalline is briefly summarized.

The Grenville series of the Original Laurentian area probably illustrates the most perfect section of Laurentian rocks which we can yet recognize. This section shows various kinds of gneisses, foliated and stratified, with foliated and massive granites and syenites, pyroxenic, dioritic, hornblendic, and quartzose rocks, and quartzite and limestone. In the basal beds of the limestone and quartzite, supposed to constitute the upper member of the series, are interstratified bands of rusty quartzose gneiss, which from the available evidence is believed to form an integral part of the limestone series. This portion presents in its banded arrangement of quartzose and calcareous rocks, the usual aspect of true altered sedimentary strata. The same well banded arrangement is also visible in some of the directly underlying gneiss; but in the case of the great mass of this gneiss, the microscopic examination shows the evidence of an aqueous origin to be wanting. Some portions of the igneous rocks are undoubtedly older than the limestones, and most probably represent the lowest portions of the earth's crust known to us. Other portions are clearly established to be of more recent age than the crystalline limestone. The oldest gneisses are foliated, rather than stratified, but in their foliation they underlie the regular series of stratified hornblende and other gneisses which occur frequently between the fundamental gneiss and the crystalline limestone and quartzite series at the summit of the section. To this fundamental series may be assigned the rocks of Trembling Mountain, those forming the anticlinals north of Lachute, rocks from various places throughout the Grenville district, and large areas at

[1] The physical features and geology of the route of the proposed Ottawa Canal between the St. Lawrence River and Lake Huron, by R. W. ELLS and A. E. BARLOW. Proc. and Trans. Roy. Soc. of Canada, 2d ser., Vol. I, Sec. IV, 1895, pp. 163–190. With sketch map.

different places along the Upper Ottawa River section. Concerning many of the intermediate gneisses, it may be said that while in their general aspect they resemble stratified sedimentary rocks, their study under the microscope shows them to have presumably a different origin, so that it is possible that the true altered aqueous portion may be confined to the areas of crystalline limestone with their associated bands of quartzite and grayish quartzose and hornblende gneiss. The crystalline limestones are particularly developed along the Ottawa River section, from the vicinity of Deschenes Lake, west of Ottawa city, to the village of Bryson, in which section they are frequently cut by large areas of granitic and dioritic rocks. At one place, near the Chats, the limestone is overlain by a considerable breadth of Huronian-looking schists, etc., which have been described under the name of Hastings series. The limestone has its most westerly outcrop on the Ottawa in the vicinity of Coulonge Lake, a short distance west of the Black River. From here west to the mouth of the Mattawa the limestone occurs as separate belts occupying synclinals in the upper stratified gneisses.

The rocks along the route of the Mattawa and French Rivers to Lake Huron are chiefly those which have been regarded as Laurentian gneisses. There is very little of the crystalline limestone which forms such an abundant constituent of the Laurentian farther east, and this, as well as the apparent inferior position of the gneisses, according to their banding, caused them early to be placed at the very base of the geological series, and called the Lower Laurentian series. Crystalline limestone occurs at Talon Lake, on the east shore of the Great Manitou or Newman Island in the eastern part of Lake Nipissing, as well as on two of the small islands composing this group, and on Iron Island. All the evidence seems to point to the fact that the limestone has been caught up in the gneisses during its eruption.

The foliation of the gneisses is produced either by (1) alternation of light and dark bands, or (2) by the more or less parallel distribution of the component minerals. In many of the plutonic rocks, and particularly in the granites and similar rocks, there is a marked tendency for the bisilicates to aggregate themselves in certain belts or patches (called Auscheidungen in the granites). The result of pressure on a rock characterized by the presence of these masses would be the flattening of the dark areas into more or less lenticular areas. Again, many of the dark bands are seen to have had their

origin as dikes, which have been intruded along the planes of foliation.

Smyth[1] describes pre-Cambrian diabase dikes cutting the granites and gneisses of the Admiralty Group of the Thousand Islands, St. Lawrence River. C. K. LEITH.

[1] A group of diabase dikes among the Thousand Islands, St. Lawrence River, by C. H. SMYTH. Trans. N. Y. Acad. Sci., Vol. XXIII, 1893–4, pp. 209–214.

Reviews.

The Naples Fauna (Fauna with Manticoceras intumescens) in Western New York. By John M. Clarke. 16th Ann. Rep. N. Y. State Geol., pp. 31–165, Plates I–IX.

The faunas of the Upper Devonian period in New York, are of great interest to all students of the geologic phases of palæontology. In the earliest fauna of this period, the Cuboides fauna of the Tully limestone, there appear suddenly several new types of organisms, chiefly brachiopods, among which the most important is *Hypothyris cuboides*, which have no genetic predecessors in the region. These strangers or exotic forms, therefore, must be considered as migration species whose previous evolution had taken place in some other geologic province, but which, with the establishment of some new line of communication at the beginning of Upper Devonian time, were enabled to find their way into the New York province. By a careful study of this Cuboides fauna and its geographic distribution, Professor H. S. Williams has been led to the conclusion that it first developed in the European or Eurasian province and later migrated into North America, coming in from the northwest along the Mackenzie basin, moving southward and finally eastward into the New York province.

The Naples or Intumescens fauna, which is the subject of Professor Clarke's paper, is a successor of the Cuboides fauna in western New York. Like the latter it is a widely distributed fauna in Europe, and it is always characterized by the goniatite genus *Manticoceras* of which the species *M. intumescens* is the common European form. Outside of New York the fauna characterized by this type of goniatite is found in North America only in Iowa and in the Mackenzie basin. In these two localities the characteristic goniatite is but sparsely represented, but in western New York it is present in considerable abundance and is represented by numerous species. From the evidence, therefore, it would seem that this fauna also found its way from Europe into North America by the same path along which the Cuboides fauna had migrated, but at a little later time. Along the way it left but slight

traces, but when it reached that part of the Upper Devonian seas which is now western New York, it found a wonderfully congenial environment and blossomed out anew.

The strata occupied by the normal Intumescens fauna are those of the typical Portage series of Hall in western New York. The fauna makes its first appearance, however, in the Styliola limestone in the midst of the Genesee shale, after which it disappears during the deposition of the Upper Genesee shales, to reappear in the Portage beds. Such a preliminary appearance of a new fauna, before it becomes an established normal fauna, is called by Professor Clarke a *prenuncial* fauna. The Styliola limestone, therefore, contains the prenuncial Intumescens fauna.

Further east, in the Ithaca section, the Intumescens fauna never became the normal fauna, but there existed contemporaneously with it a fauna which was constituted in large part of a recurrence of Hamilton species. Occasionally, however, a species of *Manticoceras* wandered into this region from the west and is found associated with the Ithaca fauna.

From this relation of faunas it will be readily seen that the term Portage cannot be used both in a stratigraphic and in a faunal sense. If it is used as a faunal name it must be restricted to the Intumescens fauna, the fauna of the original Portage rocks. If it is used as a stratigraphic name to include all those strata in New York which were deposited during a given portion of Upper Devonian time, it will include at least two quite distinct faunas. For the expression of the time duration and the geographic restriction of a particular faunal province, a technical term is often needed; a term which has not only a time significance, but a geographic significance as well. For this Professor Clarke has proposed the term *Zoehemera;* thus the zoehemera of *Manticoceras intumescens* would be the time during which the Intumescens fauna existed in the restricted geographic area in which it was distributed.

Professor Clarke's paper is devoted entirely to the cephalopods of the fauna, but the reader is led to believe that the remaining classes will be discussed at an early date. Of the cephalopods thirty species and varieties are recognized, twenty-one of them being described as new. Thirteen of the forms belong to the characteristic Intumescens fauna genus, *Manticoceras*. Under the older conception of species of goniatites nearly all of these might perhaps be included in the one

general species *M. intumescens*, but with the modern methods of ontogenetic study of the cephalopods, which have been used in a most satisfactory way in conducting this investigation, specific lines are drawn with far greater precision. The ontogenetic stages of most of the species are carefully described and fully illustrated by many figures in the text, so that the paper is valuable to the biologist as well as to the geologist.

STUART WELLER.

Geological Survey of Canada, Annual Report. New Series, Vol. IX, 1896. DR. G. M. DAWSON, Director.

During the year work was done in British Columbia, Alberta, Ontario, Quebec, Nova Scotia, Labrador, and the region west of Hudson Bay.

In British Columbia Messrs. McConnel and McEvoy gave their attention to the mining region around Nelson, Trail and Rossland. Some important facts are noted regarding the occurrence of ores. A boring in the Cretaceous formation at Athabasca Landing, Alberta, was carried to a depth of 1770 feet in the hope of reaching the petroleum-bearing "tar-sands" which form part of the lowest member of that formation to the northeast. The boring had to be abandoned, but other attempts will be made.

The report of Mr. J. B. Tyrrell on his work in the unexplored region west of Hudson Bay is one of special interest. He gives an historical sketch of earlier explorations of Hudson Bay and adjacent lands, many of which were connected with the search for a "Northwest Passage." The formations observed include the Recent, Pleistocene, Silurian, Cambro-Silurian, Cambrian, Huronian and Laurentian, of which the last is by far the most extensive. Pleistocene sea beaches and terraces are found at heights of 100 to 600 feet above sea level. In several places series of four to seven terraces mark shore lines of later glacial and postglacial times. The glacial geology of the region is accorded about twenty pages of the report. Several centers of glacial outflow are noted, about 140 strial directions recorded and many eskers, drumlins, moraines and extra-glacial lakes are described. A map accompanies the report.

Dr. Bell's report on his work in Ontario consists of a correlation of reports of work done at various times on the area of the French

River sheet. A new map is issued. Dr. Adams and Mr. Barlow worked on the area of central eastern Ontario covered by the Haliburton sheet. This is a region of much importance in the determination of the relationships of the various members of the Archean, and the results of Dr. Adams' investigations when completed will throw much light on the problem. Already many important facts have been brought out. An important discovery of corundum in Hastings county is announced. The work of mapping the Rainy River gold-bearing region was continued by Mr. McInnes. Dr. Ells continued the work in the area between the Ottawa and St. Lawrence rivers.

The observations on glaciation in southeastern Quebec by Mr. Chalmers show two periods of glaciation. In the first, which appears to have been local and centered in the Notre-Dame mountains, the ice moved northward to the St. Lawrence valley. The second was the Laurentian. The bowlder clays of the two differ lithologically. Marine shore lines show changes of level amounting to 600 or 700 feet in Pleistocene times. Slight postglacial dislocations of the slates were observed in many places. Dr. Bell reports on field work in the region of the Upper Ottawa and Rupert rivers and Mistassini Lake.

Mr. A. P. Low continued his exploration in northern Labrador between Hudson Bay and Ungava Bay. The rocks are principally Archean, but considerable areas of Cambrian were found. The land was completely covered by the glacial ice-sheet. The névé region seems to have been near the present watershed. On the western slope the ice moved nearly westward veering slightly to the south. On the eastern slope its initial direction was eastward but its final direction was northward to Ungava Bay. On the western slope the eskers correspond in direction with the present drainage lines, which, however do not agree with the direction of ice movement. The unstratified drift is generally in hills of irregular form and direction. The bowlders are generally of local origin. The highest marine terrace seen on the Hudson Bay side was 710 feet above sea level while the highest on the eastern slope was 620 feet above the sea.

Dr. Bailey and Mr. Fairbault worked in the gold-bearing Cambrian region of Nova Scotia, where mining is quite active.

The Chemical and Mineralogical Report by Dr. Hoffman contains the results of many analyses and assays. The report on Mineral Statistics and Mines is very complete.

R. D. George.

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